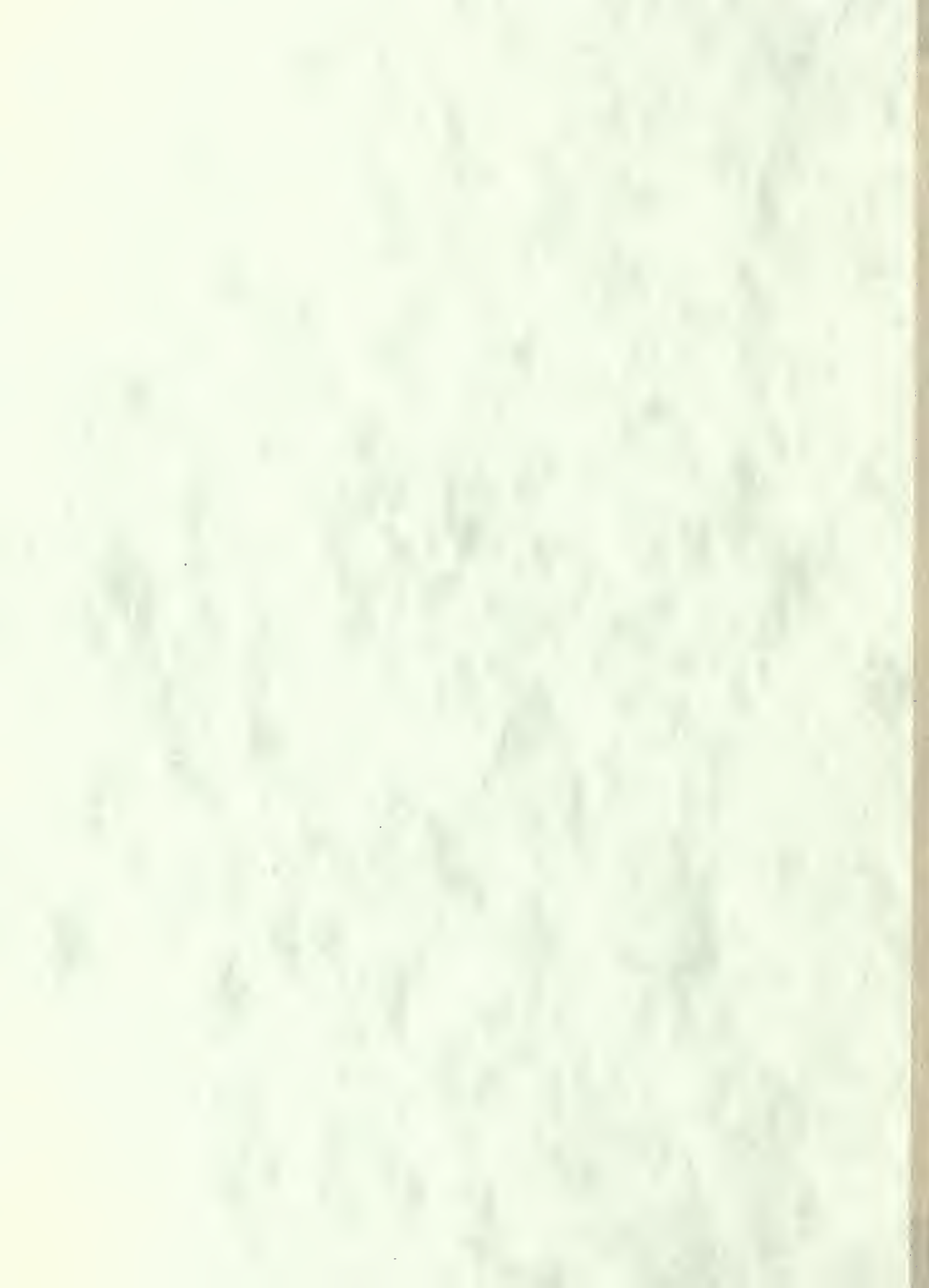


630.7
I26b
no.779
cop.8



UNIVERSITY OF
ILLINOIS LIBRARY
AT URBANA-CHAMPAIGN
AGRICULTURE

UNIVERSITY OF ILLINOIS
AGRICULTURE LIBRARY

CIRCULATING COPY
AGRICULTURE LIBRARY

FOODSERVICE SYSTEMS: TIME AND TEMPERATURE EFFECTS ON FOOD QUALITY

Barbara P. Klein, M. Eileen Matthews, and Carole S. Setser

North Central Regional
Research Publication No. 293
Illinois Bulletin 779

Agricultural Experiment Station
College of Agriculture
University of Illinois at Urbana-Champaign

Abstract

A survey of the literature on the effects of time and temperature on food quality in foodservice systems was conducted. The findings and data from these research studies and those conducted by the North Central Regional Research Committee 120 are summarized in chapters on microbiological safety, nutrient retention, and sensory quality. An overview of food product flow in the foodservice industry is also provided, and possible directions for future research are discussed. An extensive bibliography is provided.

Keywords: Foodservice systems, microbiological safety, nutrient retention, sensory quality, food product flow, food quality

FOODSERVICE SYSTEMS: TIME AND TEMPERATURE EFFECTS ON FOOD QUALITY

**Barbara P. Klein, Associate Professor
Department of Foods and Nutrition
University of Illinois at Urbana-Champaign**

**M. Eileen Matthews, Professor
Department of Food Science
University of Wisconsin — Madison**

**Carole S. Setser, Assistant Professor
Department of Foods and Nutrition
Kansas State University**



**Agricultural Experiment Stations of Illinois,
Indiana, Iowa, Kansas, Michigan, Minnesota,
Missouri, Nebraska, North Dakota, Ohio, South
Dakota, and Wisconsin, and the U.S. Department
of Agriculture, cooperating**

**North Central Regional
Research Publication No. 293
Illinois Bulletin 779
June, 1984**

**The participating agricultural experiment stations provide
equal opportunities in programs and employment.**

Sponsored by the Agricultural Experiment Stations of Illinois, Iowa, Kansas, Michigan, Missouri, Nebraska, Ohio, and Wisconsin and the Cooperative State Research Service (CSRS) and the Northern Regional Research Center (NRRC), U.S. Department of Agriculture.

This report is based on work carried out by North Central Regional Research Committee 120 on Quality and Safety of Foods in Households and Food-service Systems. Contributors and participants in this report were:

Illinois — Barbara P. Klein
Iowa — Nancy E. Brown, Jane D. Love, and Mark H. Love
Kansas — Carole S. Setser
Michigan — Carol A. Sawyer and Mary E. Zabik
Missouri — Nan F. Unklesbay
Nebraska — R. Burt Maxcy
Ohio — Marion L. Cremer
Wisconsin — M. Eileen Matthews
CSRS, USDA — George J. Mountney
NRRC, USDA — George N. Bookwalter
Administrative Advisers — Max Lennon (Missouri) and John A. Miller (Illinois)

Appreciation is expressed to P.O. Snyder, graduate student at the University of Wisconsin, for her assistance with the bulletin.

Contents

Foodservice Systems	1
Types of Systems	1
Monitoring	3
Equipment	3
Critical Control Points in Foodservice Management	6
Microbiological Safety Studies	8
Ready-Prepared Foodservice Systems	8
Conventional Foodservice Systems	10
Commissary Foodservice Systems	12
Comparisons among Foodservice Systems	13
Nutrient Retention Studies	14
Macronutrients	15
Thiamin	15
Riboflavin	17
B ₆	17
Ascorbic Acid	17
β -Carotene	18
Sensory Quality Studies	18
Sensory Quality after Hot-Holding	18
Effect of Equipment on Sensory Quality	19
Temperature and Sensory Acceptability	19
Effect of Foodservice System on Sensory Quality	20
Approaches to Prediction of Food Quality	25
Future Research Directions	26
References	27

This bulletin brings together data from research studies on the effects of time and temperature on food quality in foodservice systems. The need for these data and for their compilation has become more pressing in recent years as the foodservice industry has expanded and as new foodservice systems have been developed.

The expansion of the foodservice industry is reflected in the increased amounts of food purchased by foodservice establishments (49 billion pounds in 1979 compared with 37 billion pounds in 1969), in the increased portion of the food dollar that goes for meals and snacks away from home (37 cents in 1981 compared with 26 cents in 1960), and in the growing retail value of food served away from home (\$102.4 billion in 1979 and a projected \$157.0 billion in 1984) (Van Dress, 1982; Van Dress and Putnam, 1983; NRA, 1983). The causes for this growth are primarily

long-term demographic and social trends that should continue to favor the foodservice industry: more dual-income families, more single dwellers, larger disposable incomes, and smaller families (NRA, 1983).

The development of research data has not, however, paralleled the expansion of the foodservice industry. Nevertheless, a compilation of the data that do exist will indicate the extent of our knowledge of time and temperature effects on food quality and thus help point the direction for research that will aid the foodservice industry.

The first section of this bulletin provides a brief, selective overview of food product flow in the foodservice industry in order to delineate some of the time and temperature problems that face the industry. The subsequent sections summarize the studies that have examined the microbiological, nutritional, and sensory quality of foods prepared under various foodservice systems.

Foodservice Systems

The National Restaurant Association divides the foodservice industry into three groups (see list on page 2). Group I includes commercial eating and drinking establishments, food contractors, lodging places, and miscellaneous types of foodservices. The greatest increase in sales continues to occur in the fast-food (limited-menu) restaurants within this group (NRA, 1983). Group II includes institutional eating places such as schools, businesses that serve food to their employees, universities, hospitals, and other types of health facilities. This group accounts for approximately 40 percent of the retail value of all food consumed away from home (Van Dress, 1979). Group III includes the military feeding operations in the continental United States only.

In the last 20 to 25 years it has become increasingly popular for the foodservice establishments in all these groups to centralize food production in order to produce high-quality, nutritious foods and to minimize the use of resources, increase productivity, and decrease food and labor costs (Unklesbay et al., 1977). As a result, menu items may now be handled and processed according to various flow patterns involving different time and temperature relationships. In general, these patterns have increased the time between the initial handling of menu items and their serving.

Types of Systems

Four principal types of foodservice systems are used in the foodservice industry: commissary, conventional, ready-prepared, and assembly-serve (Unklesbay et al., 1977).

*Forecast for the Foodservice Industry —
Food and Drink Sales Projected for 1984*

GROUP I — Commercial Feeding^a

	(thousands)
Eating and drinking places	
Restaurants, lunchrooms	\$ 49,932,552
Limited-menu restaurants, refreshment places	41,229,622
Commercial cafeterias	2,806,276
Social caterers	881,433
Ice cream and frozen custard stands	1,841,611
Total eating places	\$ 96,691,494
Bars and taverns	9,844,883
Total eating and drinking places	\$106,536,377
Food contractors	
Manufacturing and industrial plants	\$ 2,571,979
Commercial and office buildings	816,948
Hospitals and nursing homes	1,091,066
Colleges and universities	1,677,802
Primary and secondary schools	761,233
In-transit feeding (airlines)	734,582
Recreation and sports centers	1,266,780
Total food contractors	\$ 8,920,390
Lodging places	
Hotel restaurants	\$ 5,946,039
Motor hotel restaurants	1,034,859
Motel restaurants	1,715,739
Total lodging places	\$ 8,696,637
Retail host restaurants ^b	4,323,349
Recreation and sports ^c	1,829,894
Mobile caterers	572,891
Vending and nonstore retailers ^d	3,038,705
Total Group I	\$133,918,243

GROUP II — Institutional Feeding (business, educational, governmental, or institutional organizations operating their own foodservice)

Employee feeding ^e	\$ 1,936,266
Public and parochial elementary and secondary schools	2,628,898
Colleges and universities	3,286,328
Transportation	882,127
Hospitals ^f	8,546,245
Nursing homes, homes for aged, blind, orphans, mentally and physically handicapped ^g	3,018,751
Clubs, sporting and recreational camps	1,620,691
Community centers	332,656
Total Group II	\$ 22,251,962
Total Group I and II	\$156,170,205

GROUP III — Military Feeding^h

Officers and NCO clubs ("open mess")	\$ 563,905
Foodservice — military exchanges	280,306
Total Group III	\$ 844,211

GRAND TOTAL **\$157,014,416**

SOURCE: Adapted from National Restaurant Association, NRA News, Vol. 3, No. 11, December 1983, Washington, D.C.

^a Data are given only for establishments with payroll.

^b Includes drug and proprietary store restaurants, general merchandise store restaurants, variety store restaurants, food store restaurants, grocery store restaurants, gasoline service station restaurants, and miscellaneous retailers.

^c Includes drive-in movies, bowling lanes, and recreation and sport centers.

^d Includes sales of hot food, sandwiches, pastries, coffee, and other hot beverages.

^e Includes industrial and commercial organizations and seagoing and inland waterway vessels.

^f Includes voluntary and proprietary hospitals; long-term general, T.B., nervous, and mental hospitals; and sales or commercial equivalent to employees in state and local short-term hospitals and federal hospitals.

^g Sales (commercial equivalent) calculated for nursing homes and homes for aged only. All others in this category make no charge either in cash or in kind for food served.

^h Continental United States only.

Commissary foodservice (also known as the satellite, central commissary, commissariat, or food factory system). In this system, food is procured and produced at a central location. The prepared items are sent to remote areas for final preparation and serving. After the food has been produced, it may be frozen, chilled, or held hot. When necessary, it may be reheated at the central location or the remote site.

Conventional foodservice (the cook/serve or cook/hot hold system). In this system, food is procured and produced within the facility where it is to be served. The preparation is finished as close to serving time as possible. Food is then held on steam tables or other types of hot-holding equipment and placed onto plates while hot. Plated food may then be served to the consumer, or, as in health care facilities, transported to the consumer in various types of carts that contain heat maintenance systems (Mahaffey et al., 1981).

Conventional foodservices thus keep food hot for two periods, once before serving and again at the point of serving. Prolonged holding times and the accompanying fluctuations in temperature are undesirable because they reduce sensory and nutritional quality and result in questionable microbiological safety.

Ready-prepared foodservice (the cook/chill or cook/freeze method). Menu items in this system are prepared in advance of service and then chilled or frozen until shortly before they are to be served. Frozen meals may be prepared far in advance (days or weeks), and chilled meals may be prepared 24 hours ahead. Food may be plated before chilling or freezing, or it may be plated immediately before distribution. Food items that are plated and chilled may or may not need to be reheated. Food items may be reheated in a microwave, conventional, or convection oven or other heating unit. Chilled, plated menu items can be placed into a cart that serves as both the refrigerator and reheat oven.

Entrees and vegetables thus receive two heat treatments in the ready-prepared system; the first when the food is initially prepared in quantity, and the second immediately before service. Foods on the menu can be chilled or frozen for varying lengths of time.

Assembly-serve foodservice. In this system, completely prepared or processed foods (usually frozen) are heated at the point of assembling and serving the meal. Bulk, preportioned or preplated prepared foods may be tempered and reheated by a convection or microwave oven or by an alternate type of heating system.

Monitoring

As these brief descriptions indicate, considerable managerial competence is required to design controls to monitor the quality and safety of foods and the time and temperature relationships of menu items along the path from procurement to consumption. Although the exact number of areas that require monitoring vary from system to system, Unklesbay et al. (1977) identified nine general areas that require precise monitoring: (1) procurement, (2) storage, (3) packaging, (4) preprocessing, (5) heat processing, (6) storage following heat processing for heated, chilled, and frozen food, (7) heat processing of precooked menu items, (8) product distribution, and (9) serving.

In setting and monitoring controls for any of these areas, a foodservice administrator is faced with many decisions that involve satisfying safety requirements while maintaining nutritional and sensory quality. Requirements stated in the Foodservice Sanitation Manual (USDHEW, 1978) are that "potentially hazardous foods (any food that consists in whole or in part of milk, or milk products, eggs, meat, poultry, fish, shellfish, edible crustacea or other ingredients, including synthetic ingredients, in a form capable of supporting rapid and progressive growth of infectious or tox-

igenic microorganisms) that have been cooked and then refrigerated shall be reheated rapidly to 74°C/165°F or higher throughout before being served or before being placed in a hot-food storage facility." However, Paulus et al. (1978) cited a center temperature of only 70°C/158°F as being detrimental to the sensory (particularly the color and texture) and nutritional quality of reheated vegetable-based dishes. On the other hand, foods that are plated hot can have a minimum temperature of 60°C/140°F for microbial control (USDHEW, 1978).

Administrators must also monitor the time necessary to complete each step in the food flow process so that a detrimental increase or decrease in temperature does not occur. For example, the time needed to assemble and distribute a meal can be crucial to the microbial, nutritional, and sensory quality of food in a facility that must assemble hundreds or thousands of meals in advance. Health care institutions and large foodservice meal fabricators, for example, usually assemble meals on a belted tray line with foodservice personnel working alongside the line adding individual menu items to trays according to predetermined patterns. In a hospital, time for meal assembly on the tray line may average from two to six trays per minute. A 500-bed hospital averaging four trays per minute thus would require approximately 2 hours for meal assembly.

Although such time periods are viewed as microbiologically safe (USDHEW, 1978), 2 hours could cause undesirable changes in food temperature when food is not properly refrigerated or held hot throughout the meal assembly process. For example, the temperature of milk or gelatin would rise from 7°C/45°F to 13°C/55°F in less than 1 hour at room temperature and would reach room temperature in 2 hours. Even if the milk or gelatin were subsequently to be refrigerated for meal distribution, its temperature still would probably not be lowered enough for optimal sensory satisfaction at service.

Choosing to assemble the foods in a refrigerated or air-conditioned environment would not solve the problem since the refrigerated environment could then decrease the temperature of the hot foods being assembled. Thus, when assembly is completed in an air-conditioned or refrigerated environment, the surface and interior temperature of hot food must be monitored throughout the assembly.

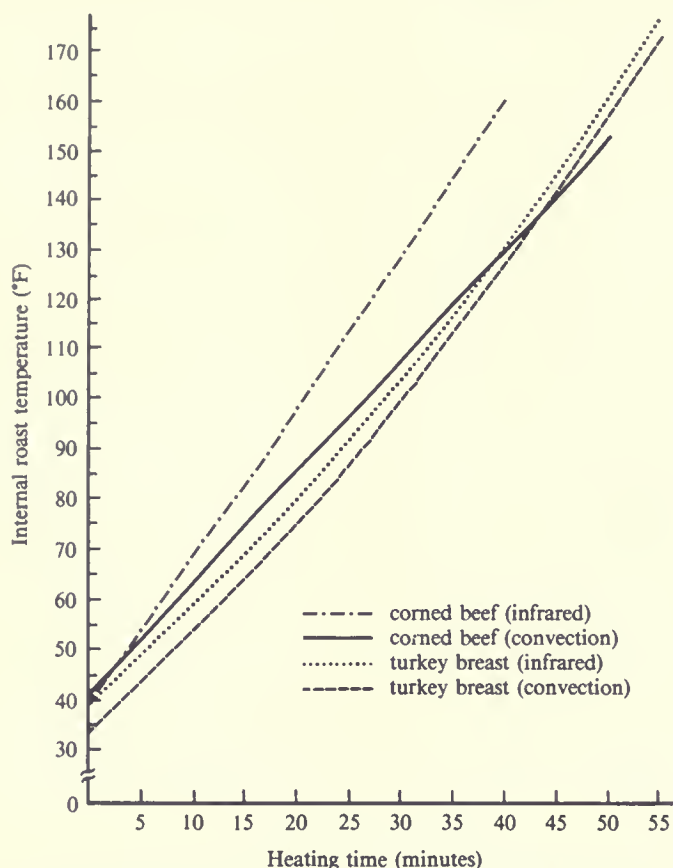
Distribution of the assembled food adds further time and temperature stress, primarily through the possibility of delays, equipment malfunction, or human error. For example, food held hot too long may dehydrate, while cold food held in close proximity to heated food, such as milk on a tray in a pellet system, may increase in temperature. Distribution problems with equipment may range from carts without adequate heat support systems to old or inadequate equipment that may widen the temperature band of portioned foods over time.

Equipment

The adequacy and reliability of equipment is, in fact, a critical factor in all areas of the food flow process. The effectiveness of equipment in bringing hot food to the recommended temperature (74°C/165°F) and keeping cold food at the recommended temperature (7°C/45°F) is particularly critical (USDHEW, 1978; Longree, 1980).

Various kinds of equipment are used in foodservice systems. Heating equipment includes conventional, microwave, infrared, and convection ovens. Cooling equipment includes walk-in or roll-in refrigerators, the use of circulating liquids, and blast or liquid nitrogen freezing units.

Rate of heating. One measure of the adequacy of equipment is the rate of heating. Food quality and safety are dependent upon the rate at which the equipment can heat the menu items. The rate of heating also imposes time constraints



Mean initial temperatures and predicted increases in internal temperatures for corned beef and turkey breast thermally processed in both infrared and forced-air convection ovens (Benderwald, 1978).

on the foodservice operation. A few studies have compared the heating rates of various types of equipment, but much more research is needed to evaluate the influence of heating rate on food quality and microbiological safety.

Among the comparative studies is one by Benderwald (1978), who found a faster rate of cooking in infrared than in convection ovens (see figure above). In another study, microwave ovens were significantly ($p \leq 0.01$) faster than conventional ovens (at $163^{\circ}\text{C}/325^{\circ}\text{F}$) in cooking meat loaves to a final internal temperature of $74^{\circ}\text{C}/165^{\circ}\text{F}$ (Ziprin and Carlin, 1976). The rate of heat penetration between $4^{\circ}\text{C}/39^{\circ}\text{F}$ and $74^{\circ}\text{C}/165^{\circ}\text{F}$ was 3.7°C per minute for loaves in the microwave and 0.9°C per minute for loaves in the

conventional oven. Voris and Van Duyne (1979) found that top round beef roasts cooked to an internal temperature of $68^{\circ}\text{C}/155^{\circ}\text{F}$ faster in microwave ovens than in conventional ovens (at $149^{\circ}\text{C}/300^{\circ}\text{F}$). However, Ziprin and Carlin found that microwave cooking increased cooking losses and decreased the moisture content and thiamin retention in the meat loaves, while Voris and Van Duyne found no significant difference between the microwave and conventional oven in the total cooking losses, moisture, fat, thiamin, tenderness, juiciness, or interior color of the round roasts.

Decareau (1978) found that there were substantial differences in rates of heating in food items in a fully loaded convection oven. When

food in one area of the oven was heated to $72^{\circ}\text{C}/162^{\circ}\text{F}$, food in other areas was seriously undercooked.

Uniformity and consistency of heating and cooling. Another critical factor in maintaining food quality is the consistency of the equipment used in uniformly heating or cooling all food to the proper temperature. The results of numerous studies done on uniformity suggest that foodservice administrators should continually monitor temperature and carefully follow manufacturer's directions for subsystem operations such as plating, menu design, and time and temperature of heating and cooling. It is important to note, however, that manufacturers do not always provide adequate instructions for equipment operation. Therefore, heating and cooling procedures must be carefully controlled.

The end-point temperature (EPT) of food after reheating may exhibit a broad range if all portions are monitored. Sawyer et al. (1983) prepared beef loaf, potatoes, and peas in a simulated hospital cook/chill foodservice system to compare EPTs of foods after reheating in conduction, convection, and microwave reheat subsystems (according to the manufacturer's directions). Mean EPTs and standard deviations appear in Table 1. According to the Food Service Sanitation Manual (USDHEW, 1978), all EPTs of beef loaf and potatoes should have been $74^{\circ}\text{C}/165^{\circ}\text{F}$ or greater, but often the food did not reach this temperature (Table 2). When beef loaf, potatoes, and peas were portioned and plated before reheating, the percentage of time that the EPTs were lower than $74^{\circ}\text{C}/165^{\circ}\text{F}$ increased (Table 2). When food items were reheated as a meal, the conduction reheat subsystem had the largest mean percent time (80 percent) when EPT did not reach $74^{\circ}\text{C}/165^{\circ}\text{F}$. The conduction reheat subsystem was the only subsystem in which the time and temperature were preset by the manufacturer.

Bengtsson (1979) showed temperature ranges of 20 to $40^{\circ}\text{C}/68$ to

Table 1
Cook/Chill Foodservice System: End-Point Temperature after Conduction, Convection, and Microwave Reheat

Reheat method and product	Number of trials	End-point temperature (°C), mean $\pm$ standard deviations
Conduction	15 to 17	
Beef loaf		74.5 $\pm$ 4
Potatoes		80.1 $\pm$ 5
Peas		86.5 $\pm$ 2
Convection	14 to 18	
Beef loaf		74.7 $\pm$ 12
Potatoes		62.5 $\pm$ 12
Peas		76.9 $\pm$ 7
Microwave	12 to 23	
Beef loaf		77.6 $\pm$ 1
Potatoes		75.9 $\pm$ 1
Peas		78.0 $\pm$ 2

SOURCE: Sawyer et al. (1983).

Table 2
Cook/Chill Foodservice System: Percentage of Time End-Point Temperature of Foods Was Less Than 74°C/165°F after Reheating

Reheat method and product	Reheat subsystem		
	Conduction	Convection	Microwave
	(percent)		
Single-item reheating^a			
Beef loaf	31	53	4
Potatoes	31	50	10
Peas	0	15	0
Mean	21	39	5
Reheated as a meal^b			
Beef loaf	75	75	22
Potatoes	83	75	0
Peas	83	13	0
Mean	80	54	7

SOURCE: Sawyer et al. (1983).

^a Number of trials = 3 to 12.

^b Number of trials = 2 to 8.

104°F in food in a forced-air convection oven operating at 250°C/482°F (unloaded), resulting in a temperature range of 35°C within and between samples of food. Dahl and Matthews (1979) reported similar figures for beef loaf cooked in a forced-air convection oven.

The consistency of equipment from one load to the next and from one machine to another has also been shown to be a problem. Spaghetti and chili heated in a single convection oven in a school foodservice system had end-point temperatures ranging from 34 to 98°C/

93 to 208°F (Cremer and Chipley, 1977a). When spaghetti was heated in four different convection ovens in the same system, temperatures below 74°C/165°F were found in three of four ovens and significant ($p \leq 0.01$) differences were found in overall mean temperatures between ovens and according to the position of food within the ovens.

Temperatures of scrambled eggs ranged from 35 to 92°C/95 to 198°F and temperatures of roast beef from 43 to 93°C/109 to 199°F after heating in microwave ovens in a hospital system (Cremer and Chipley, 1980a,b). A study of scrambled eggs heated in three microwave ovens in the same system revealed that temperature could be controlled to the extent of $\pm 5^\circ\text{C}$, with 96 percent of the temperatures above 74°C/165°F (Cremer, 1981). Comparison of temperature variability resulting from heating in microwave and convection ovens revealed variability of $\pm 6^\circ\text{C}$ for both beef patties and scrambled eggs heated in a microwave oven compared with a variability of $\pm 12^\circ\text{C}$ for beef patties and $\pm 14^\circ\text{C}$ for scrambled eggs heated in a convection oven (Cremer, 1982).

In yet another study, some of the equipment in six flight kitchens servicing five airlines could not maintain food temperatures above 60°C/140°F or below 7°C/45°F, and temperature variability was found for food heated in convection ovens (Bryan et al., 1978).

Cooling equipment must be just as closely monitored as heating equipment. In one hospital ready-prepared foodservice system, refrigeration equipment was found to be ineffective in reducing temperatures to 7°C/45°F (Cremer and Chipley, 1980a,b). The temperature of scrambled eggs was lowered to only 11°C/52°F after 10 hours of storage, and the temperature of roast beef was only 8°C/46°F after 20 hours of storage, in walk-in or roll-in type refrigerator units.

In a school foodservice operation, a water-glycol solution circulating in jacketed tanks was effective in cooling 80 gallons of spaghetti or

chili from 74°C/165°F or above to 7°C/45°F or below in less than 2 hours (Cremer and Chipley, 1977a).

Reheat equipment. The importance of equipment in the food flow process can be seen by examining the possible equipment choices in just the reheating step of the process. Each type of equipment that could be used to reheat food has its own particular time and temperature capabilities.

Forced-air convection ovens are commonly used to reheat pre-cooked foods in bulk or in single portion trays. The reheating time in a convection oven can vary, depending upon how well the heating power is balanced to the rate of heat uptake of the food load (Bengtsson, 1979). As noted earlier (Bengtsson, 1979; Dahl and Matthews, 1979), wide temperature bands can be observed in forced-air ovens.

Steam injection improves the performance of forced-air convection ovens because it raises the relative humidity of the air and reduces surface evaporation from products, thereby increasing the heating rate. Bengtsson (1979) cited decreased cooking time as an additional advantage of steam injection. Thus, controlled steam injection should be considered as a means of equipment redesign.

Microwave ovens are also used for reheating purposes. They increase the temperature in food, cause only about 10 percent loss of moisture and nutrient content, and lower the microbiological population (Dahl and Matthews, 1980a,b). Reheating results depend on the type, size, shape, and arrangement of food, on the power input and output of the oven, on the type of container, covered or uncovered, in which food has been placed, on the length of the heating cycle, and on the location of the food in the cavity of the oven. However, although meals are heated rapidly individually in a microwave oven, microwave ovens are slow to use in large systems where many meals (for ex-

ample, 100 meals) must be reheated (Dahl, 1982). Although heating in microwave ovens will reduce the microbial population of food, microbial safety cannot be assured, partially because of the lack of uniformity of heating.

Steam-jacketed kettles are effective for reheating foods such as stews, soups, gravies, and spaghetti sauce. One major difficulty with these kettles, especially ones over 5 gallons, is stirring, which is needed to hasten heat distribution. Without stirring, food may deposit on the heating surface and burn, resulting in a burnt off-flavor for the entire food load. Another problem in using a large steam-jacketed kettle is uneven temperature distribution on the walls because of improper venting of air and condensate inside the steam-heated mantle. This problem also can result in a burnt off-flavor.

One of the most innovative reheat subsystems designed in the 1970s was the reheat cart (Alpha Cart by Anchor-Hocking, Inc.), a food and beverage transporter used to carry food, keep chilled food cold, and reheat precooked, frozen food. This cart was designed for use at the Walter Reed Army Medical Center in Washington, D.C. Each cart held 20 patient trays. Each hot food item was individually reheated according to one of 15 preprogrammed reheating codes. A reheat cycle took 32 minutes, but erratic heating and failure to heat all foods to their desired temperature were observed (Shaw et al., 1979).

Critical Control Points in Foodservice Management

On the basis of this brief overview, it should not be surprising that time and temperature relationships were involved in five of the six major factors contributing to outbreaks of foodborne disease in the United States over a 16-year period (Table 3). These data emphasize the importance of devising methods for maintaining and controlling food safety and quality at

critical points throughout the food flow process. Tools for effective monitoring include standardized procedures, initial and end-heating temperature controls, microbial controls, and appropriate training procedures.

The concept of Hazard Analysis Critical Control Point (HACCP) was developed to help prevent undesirable quality changes in foods, particularly with respect to microbiological safety (Bauman, 1974). Using the HACCP concept, foodservice managers can analyze the steps in their food flow process to determine any hazards (or potential hazards) to the quality or safety of their food product. If the manager identifies any actual or potential hazard, critical control points should be established at those steps in the process where lack of control would result in a public health hazard. The manager should take corrective action to bring those steps in the process under control (Bryan, 1981).

During the 1970s, several applications of the HACCP concept were made in the food industry (Bauman, 1974; Ito, 1974; Kauffman, 1974; Peterson and Gunnerson, 1974), but the HACCP concept as applied to the foodservice industry was particularly refined by Bobeng and David (1977, 1978a,b). These two researchers defined quality as a multidimensional characteristic of food that includes microbiological, nutritional, and sensory attributes. They then identified four overall critical control points for HACCP models for foodservice systems: (1) ingredient control and storage, (2) equipment sanitation, (3) personnel sanitation, and (4) time and temperature parameters. The researchers then examined each step in the food flow process of several foodservice systems. For each process step shown in Table 4, they identified one or more of the four critical control points that should be particularly monitored as well as what factors contributed to microbiological control at that step.

Table 3

The Eleven Most Important Factors Contributing to the Occurrence of Outbreaks of Foodborne Disease during 1961 through 1976

Contributory factor	Rank ^a	Percent ^b
Inadequate cooling of foods	1	46
Lapse of a day or more between preparation and serving	2	21
Infected persons	3	20
Inadequate thermal processing, canning, or cooking	4	16
Inadequate hot storage	5	16
Inadequate reheating	6	12
Ingesting contaminated raw food or ingredient	7	11
Cross-contamination	8	7
Inadequate cleaning of equipment	9	7
Obtaining foods from unsafe sources	10	5
Using leftovers	11	4

SOURCE: Adapted from Bryan (1978).

NOTE: The survey reviewed 1,152 incidences reported in public health literature or surveillance data during the 16-year period.

^a Ranked in order of frequency of occurrence; thus, 1 = the major contributory factor.

^b Column adds to more than 100 percent because multiple factors are usually necessary for outbreaks of foodborne disease to occur.

Bobeng and David's fourth critical control point referred to the relationship of time and temperature at each process step of entree production. Table 4 summarizes the process steps and time and temperature critical control points for entree production in conventional, cook/chill, and cook/freeze foodservice systems. Time and temperature standards were designed to minimize the time that the temperature of entrees is in the zone of growth for microorganisms. The control points follow the temperature requirements of the Food and Drug Administration mentioned earlier (USDHEW, 1978).

The authors noted that critical control points are interdependent. Thus, loss of control at one point may result in a cumulative effect on the microbiological condition of the finished product or in loss of control at subsequent critical control points. The use of HACCP models was recommended by Bobeng and David as quality control tools. Establishing temperature standards is a practical method for monitoring food production. Adherence to minimal temperature standards for heat processes would not only control microbiological quality but also conserve the nutritional and sensory quality of the entree.

Bobeng and David (1978a) reported that it was not possible to establish universal critical control point parameters to monitor equipment and personnel sanitation because each foodservice system has different types, sizes, and models of equipment and varying kinds and numbers of positions for personnel. The authors thus recommended that the specific standards for control at the critical control points be determined in each foodservice system based on the specific objectives, resources, and constraints of the operation.

Table 4

Time and Temperature Critical Control Points in Foodservice Systems

Process steps	Foodservice system ^a	Internal temperature at the end of control-point activity	Time
Initial heat preparation	cv, c/c, c/f	7 to 60°C/45 to 140°F	variable
Hot-holding	cv	≥60°C/140°F	variable
Chilling	c/c	≤7°C/45°F	≤4 hours
Chilled storage	c/c	≤7°C/45°F	≤20 hours
Freezing	c/f	≤-20°C/-4°F	≤1.5 hours
Freezer storage	c/f	≤-18°C/0°F	≤8 weeks
Thawing	c/f	≤7°C/45°F	minimum
Portioning and assembling	c/c, c/f	≤7°C/45°F	variable
Portioning, assembling, and distribution	cv	≥60°C/140°F	minimum
Cold-holding and distribution	c/c, c/f	≤7°C/45°F	variable
Terminal heating	c/c, c/f	74 to 77°C/165 to 171°F	variable
Serving	cv, c/c, c/f	≥60°C/140°F	minimum

SOURCE: Adapted from Bobeng and David (1978a).

NOTE: The Food and Drug Administration requires that the temperature of potentially hazardous foods be 7°C/45°F or below or 60°C/140°F or above at all times, except during preparation and handling.

^a cv = conventional foodservice system; c/c = cook/chill foodservice system; and c/f = cook/freeze foodservice system.

Microbiological Safety Studies

Tables 5, 6 and 7 summarize reports since 1970 on the microbiological quality of menu items prepared under actual and simulated operations in ready-prepared, conventional, and commissary systems. Each table lists the investigator(s), year, product, and indicator of microbiological quality. For ready-prepared and commissary systems, the critical control point listed in column two is the time and temperature of the final heat treatment, while the critical control point listed for conventional foodservice systems is the time and temperature of hot-holding. Colony-forming units (CFU) indicate the microbial population remaining after the hot-holding period or final heat treatment.

Ready-Prepared Foodservice Systems

Most of the recent research on the microbial quality of menu items has focused on the ready-prepared foodservice system (Table 5). The ready-prepared system has two variations—cook/freeze and cook/chill.

Actual conditions. Nicholanco and Matthews (1978) reported on the microbiological quality of beef stew prepared in a hospital cook/chill system. Quality was determined by the numbers of coliforms and aerobic bacteria present following three stages of product handling—production, chilled storage, and assembly distribution. The coliform counts were always ≤ 10 CFU/g, but the aerobic bacteria numbers were higher when the stew had been held between 7 to 60°C/45 to 140°F.

The microbial quality of scrambled eggs at various stages of product flow in a hospital cook/chill

system was investigated by Cremer and Chipley (1980a). They found small numbers of *Bacillus* sp., *Staphylococcus epidermidis*, *Clostridium sporogenes*, *Escherichia coli*, and *Enterobacter aerogenes* in the eggs after heating for service. The presence of staphylococci and coliforms indicates post-heating contamination or inadequate heat treatment during microwave heating. Although the mean temperature was 67°C/153°F, a wide range of end-point temperatures was noted (Table 5).

Cremer and Chipley (1980b) also studied the microbiological quality of roast beef prepared in a hospital cook/chill foodservice system. After the final heat treatment, meat samples contained *Bacillus* sp., *C. sporogenes*, *Clostridium perfringens*, *S. epidermidis*, and *Staphylococcus aureus*. Small numbers of *Aspergillus* sp., *Cladosporium* sp., and *Penicillium* sp. were also isolated. The authors noted that the mean temperature (64°C/147°F) used for the final heat treatment was well below 74°C/165°F, the recommended temperature for reheating cooked food (USDHEW, 1978).

Simulated conditions. A number of laboratory studies have been done under simulated cook/chill foodservice conditions. Bunch and coauthors (1976) heated to 80°C/176°F in a microwave oven (55 seconds), beef-soy loaves that had been stored at 5°C/41°F for 24, 48, or 72 hours. The final heat treatment did not destroy all bacteria in the center of the loaves since spores can survive heating to 80°C/176°F for less than 1 minute.

In a later study, Bunch et al. (1977) inoculated *S. aureus* into beef-soy loaves to determine the fate of this organism during various stages of food handling. Again,

samples that had been stored chilled (5°C/41°F; 24, 48, or 72 hours) were heated to 80°C/176°F in a microwave oven (55 seconds). After the final heat treatment, samples representing all three storage periods had ≤ 3 CFU/g. It should be pointed out that any toxin produced by *S. aureus* would not have been inactivated by the final heat treatment used in this experiment.

Dahl et al. (1978) evaluated the microbial quality of beef loaf as it might have been prepared in hospital cook/chill systems. Beef loaves were heat-processed in a convection oven to an end temperature of 45/113, 60/140, 75/167, or 90°C/194°F, stored (6°C/43°F; 24 hours), portioned (100 grams), and microwave-heated (≥ 74 °C/165°F). The end temperature was not a significant factor in the survival of bacteria as determined by mesophilic, psychrotrophic, coliform, or streptococcal counts. The second heat treatment (≥ 74 °C/165°F) was sufficient to ensure destruction of the heat-labile population.

Using a wide range of temperatures and times (Table 5), Dahl et al. (1980a) studied the microbial quality of beef loaf, potatoes, and frozen green beans in a simulated cook/chill foodservice system. The aerobic plate count in beef loaf, potatoes, or beans was not related to the end temperature of microwave heating, regardless of the time used. When beef loaf was heated for 50 seconds to an end temperature of 60°C/140°F, the aerobic plate count was $\leq 10^3$ CFU/g. When beef loaf was heated for 110 seconds to an end temperature of 92°C/198°F, it was microbiologically safe but of poor sensory quality. Green beans heated 50, 80, or 110 seconds all had a similar range of aerobic plate counts ($\leq 10^7$ to $\leq 10^4$ CFU/g). There was enough variation in aerobic plate counts for the authors to reemphasize the need for controlling the quality of raw ingredients.

The fate of *S. aureus* in cook/chill foodservice systems before and after microwave heating was stud-

Table 5
Microbiological Quality of Menu Items Processed under Actual and Simulated Conditions in Ready-Prepared Foodservice Systems

Product	Final heating time temperature ^a	Indicator of micro- biological quality (organism or test)	Colony-forming units per gram (CFU/g)	Reference
Actual Conditions				
Beef stew	Na ^b 149°F ^c	Aerobic bacteria Coliform	66,000 ≤ 10	Nicholanco and Matthews (1978)
Scrambled eggs	30 seconds 95 to 198°F	Aerobic plate count Staphylococci Coliform Clostridia	23 to 70 ^d 0 to 7 ^d 0 to 13 ^d 10 to 27 ^d	Cremer and Chipley (1980a)
Roast beef	60 seconds 109 to 200°F	Aerobic plate count Staphylococci Coliform Clostridia Yeast and mold	500 to 1,200 ^d 240 to 520 ^d 0 280 to 380 ^d 0 to 15 ^d	Cremer and Chipley (1980b)
Simulated Conditions				
Beef-soy loaf	55 seconds 176°F ^c	Aerobic bacteria	4,000 to 5,100	Bunch et al. (1976)
Beef-soy loaf	55 seconds 176°F ^c	<i>Staphylococcus aureus</i> inoculum (5.0 × 10 ³ cells/g)	≤ 3	Bunch et al. (1977)
Beef loaf	NA ^b ≥ 165°F	Aerobic plate count (mesophilic) Aerobic plate count (psychrotrophic) Coliform Streptococcal	Beef loaf initially heated to 194°F and microwave- heated to ≥ 165°F had a mean percentage of ≤ 1 of initial count remaining	Dahl et al. (1978)
Beef loaf	20,50,80,110 seconds 86,140,196,198°F	Aerobic plate count	≤ 100,000 to ≤ 30 when heated for 20 to 110 seconds	Dahl et al. (1980a)
Potatoes	25,45,65,85 seconds 79,102,140,158°F	Aerobic plate count	≤ 1,000,000 to ≤ 100,000 when heated for 25 to 85 seconds	
Green beans, frozen	20,50,80,110 seconds 73,201,199,198°F	Aerobic plate count	≤ 10,000,000 to ≤ 10,000 when heated for 20 to 110 seconds	
Beef loaf	20,50,80,110 seconds 90,140,180,198°F	<i>Staphylococcus aureus</i> inoculum (1.0 × 10 ⁷ CFU/g)	0 after heated for 80 seconds	Dahl et al. (1980b)
Potatoes	25,45,65,85 seconds 79,106,135,162°F	<i>Staphylococcus aureus</i> inoculum (1.0 × 10 ⁷ CFU/g)	30 to 7,900 when heated for 85 seconds	
Green beans, frozen	20,50,80,110 seconds 86,201,201,201°F	<i>Staphylococcus aureus</i> inoculum (1.0 × 10 ⁷ CFU/g)	≤ 30 to 10,000 when heated for 80 seconds	
Green beans, canned	20,40,60,80 seconds 88,160,194,201°F	<i>Staphylococcus aureus</i> inoculum (1.0 × 10 ⁷ CFU/g)	≤ 30 after heating most samples for 40 seconds	
Beef loaf	20,50,80,110 seconds 86,149,183,189°F	<i>Streptococcus faecium</i> inoculum (1.5 × 10 ¹⁰ CFU/g)	≤ 30 when heated for 80 seconds	Dahl et al. (1981a)
Potatoes	25,45,65,85 seconds 86,118,127,176°F	<i>Streptococcus faecium</i> inoculum (1.9 × 10 ¹² CFU/g)	≤ 30 when heated for 85 seconds	
Beef loaf	20,50,80,110 seconds 88,136,171,194°F	Aerobic plate count	After 80 seconds of heating, all bacteria appeared to be injured	Dahl et al. (1981b)
Green beans, frozen	20,50,80,110 seconds 73,201,199,198°F	Aerobic plate count	≤ 1,000 injured bacteria when heated for 50, 80, or 100 seconds	

^a Temperature of product given as range unless indicated otherwise.

^b Not available.

^c Mean of three trials.

^d Expressed as colony-forming units per 10 grams.

ied by Dahl et al. (1980b). Beef loaf, potatoes, and frozen and canned green beans were inoculated with *S. aureus*. These menu items were prepared according to the time and temperature recommendations of the HACCP model. Beef loaf was cooked (66°C/151°F), and potatoes were heated (79°C/174°F), while beans received no initial heat treatment. Products were covered and stored (6°C/43°F; 24 hours), portioned (100 grams), covered and stored (6°C/43°F; 2 hours), and microwave-heated for a variety of times and end temperatures (Table 5). As the time of microwave heating increased, the number of *S. aureus* in menu items decreased. However, microwave heating did not consistently result in an end temperature of 74 to 77°C/165 to 171°F as given in the HACCP model. Moreover, the destruction of *S. aureus* was not consistent at the mean end temperature of 74 to 77°C/165 to 171°F. Results from this study cannot be used to predict the behavior of *S. aureus* in food products heated by microwave energy. If the dielectric properties of food are determined, however, heating effectiveness can be predicted.

Dahl et al. (1981a) selected *Streptococcus faecium* as the indicator microorganism to evaluate the safety of beef loaf and potatoes following microwave heating in a simulated cook/chill foodservice system. Beef loaf was cooked (66°C/151°F), chilled (6°C/43°F; 24 hours), portioned (100 grams), surface-inoculated, chilled (6°C/43°F; 2 hours), and microwave-heated for various times and to various temperatures (Table 5). Potatoes were heated (79°C/174°F), chilled (37°C/99°F), inoculated internally, stored (6°C/43°F; 24 hours), and microwave-heated for varying periods of time and to different temperatures (Table 5). Beef loaf or potatoes microwave-heated for 80 or 85 seconds had ≤ 30 CFU/g. The survival of *S. faecium* was inversely related to microwave-heating time and independent of the inoculation procedure.

In another study, Dahl et al. (1981b) investigated the effects of the process steps in cook/chill foodservice systems on the numbers of injured bacteria in beef loaf and frozen green beans after each step. Beef loaf was cooked (66°C/151°F), stored (6°C/43°F; 24 hours), portioned (100 grams), held (6°C/43°F; 2 hours), and microwave-heated to various temperatures (Table 5). Beans were removed from the freezer, stored (6°C/43°F; 24 hours), portioned (100 grams), held (6°C/43°F; 2 hours), and microwave-heated. Bacterial injury was expressed as the difference between an aerobic plate count with a standard medium and an aerobic plate count with a comparable medium plus sodium chloride. The number of injured bacteria increased as the duration of heating increased.

Conventional Foodservice Systems

Investigations of the microbial quality of menu items prepared in actual and simulated conventional foodservice systems are summarized in Table 6.

Actual conditions. A time and temperature evaluation and a bacterial survey were conducted by Bryan and Kilpatrick (1971) to determine the fate of salmonellae and *C. perfringens* in roast beef prepared in a fast-food restaurant. No salmonellae were isolated; however, 29 percent of all cooked meat was contaminated with *C. perfringens*. The temperature of roasts held in the warmer depended on a number of variables—the size of the roast, its shelf position in the warmer, its internal temperature when placed in the warmer, its post-oven temperature rise, the temperature of the warmer, and the length of time the roast was in the warmer. Overall, the internal temperature of roasts held hot in the warmer was above 50°C/122°F but seldom above 60°C/140°F. The temperature of a few roasts was found to be in

the incubation range for *C. perfringens*. Bryan and Kilpatrick stated that situations such as this could result in a hazard to the consumer.

Bryan et al. (1981) performed hazard analyses of various food handling practices used by Cantonese-style restaurants in the preparation of boiled and fried rice. Rice temperatures during the process steps, water activity, and the level of *Bacillus cereus* present in the rice were evaluated. Steam tables were operated at temperatures that would prevent the growth of *B. cereus*. However, when rice was held at room temperature, growth of *B. cereus* could occur. The authors recommended that cooked rice be held at 60°C/140°F or above to preclude the growth of *B. cereus* during the hot-holding step.

In a more recent study, Bryan et al. (1982) evaluated time and temperature at each process step involved in the preparation of roast pork in a food market and of char sui (marinated roast pork) in six Chinese restaurants. Various holding times, temperatures, and types of holding equipment were used. No salmonellae were isolated, but *S. aureus* and *C. perfringens* were both present in small numbers. Findings by Bryan et al. (1982) point to the number of opportunities available for the introduction and growth of pathogens in restaurants and markets producing Chinese-style foods. Displaying cooked foods in window counters and glass-enclosed cabinets is cited as a very hazardous practice.

Simulated conditions. Brown and Twedt (1972) cooked beef roast to an internal temperature of 60°C/140°F and then cubed its center into 50-gram samples. The surfaces of all samples were inoculated with *S. aureus*, salmonellae, or *C. perfringens*. After samples were held 6 hours at a holding temperature between 49 to 53°C/120 to 127°F, the number of bacteria on the surfaces was reduced substantially. Based on these findings, the authors suggested that the recommended holding temperature (60°C/140°F) for beef

Table 6
Microbiological Quality of Menu Items Processed under Actual and Simulated Conditions in Conventional Foodservice Systems

Product	Hot-holding time temperature	Indicator of microbiological quality (organism or test)	Colony-forming units per gram (CFU/g)	Reference
Actual Conditions				
Roast beef	<u>≤ 5 hours</u> variable	Salmonellae <i>Clostridium perfringens</i>	0 Present in 29% of the samples after cooking	Bryan and Kilpatrick (1971)
Rice, boiled or fried	<u>35 to 420 minutes</u> 210 to 162°F ^a	<i>Bacillus cereus</i>	≤ 10	Bryan et al. (1981)
Roast pork	<u>570 minutes</u> 195 to 107°F ^a	Salmonellae <i>Staphylococcus aureus</i> <i>Clostridium perfringens</i>	0 ≤ 10 ≤ 10	Bryan et al. (1982)
Simulated Conditions				
Beef roast	<u>0,6,12,18,24 hours</u> 140°F ^b	Salmonellae inoculum (3 × 10 ⁶ cells/g) <i>Staphylococcus aureus</i> inoculum (5 × 10 ⁵ cells/g) <i>Clostridium perfringens</i> inoculum (4 × 10 ^{4.5} cells/g)	≤ 300 after holding at 127°F for 6 to 24 hours ≤ 300 after holding at 120°F for 6 to 24 hours ≤ 300 after holding at 127°F for 6 to 24 hours	Brown and Twedt (1972)
Roast beef	<u>1,2,6,12 hours</u> 140°F ^b	<i>Escherichia coli</i> inoculum (1.0 × 10 ⁶ cells/cm ²) Aerobic plate count Coliform	<i>E. coli</i> was rapidly destroyed at 129°F ≤ 100,000 after holding for 12 hours at 140°F ≥ 100,000 after holding for 12 hours at 129°F 0 after 12 hours at 129°F 0 after 6 hours at 140°F	Ockerman and Dowiercial (1982)
Whipped potatoes	<u>60 minutes</u> 127 to 139°F ^c ; 136 to 154°F ^d	<i>Bacillus cereus</i> inoculum (≥ 40 CFU/20.3 cm ²)	15 to 43,000 CFU/20.3 cm ²	Snyder (1982)

^a The first value represents the temperature of the product when it was placed into the holding equipment, while the second value represents its temperature at the end of the holding period.

^b Temperature of the food product when placed into the holding equipment.

^c Range for surface temperatures over six trials of the experiment.

^d Range for internal temperatures over six trials of the experiment.

could be reduced without these particular organisms posing a threat to the consumer's health.

Ockerman and Dowiercial (1982) surface-inoculated restructured beef roast that had been cooked to an internal temperature of 60°C/140°F with *E. coli*. Roasts were then stored in a warmer at 54°C/129°F

and 60°C/140°F for 1, 2, 6, and 12 hours. *E. coli* was destroyed at both holding temperatures. However, the growth of thermophilic organisms was observed in the product at both holding temperatures.

Snyder et al. (1983) reported on the fate of *B. cereus* during preservice holding. *B. cereus* was surface-

inoculated on whipped potatoes, and the survival of the organism was determined following preservice holding typical of conventional foodservice systems (equipment temperature, 52°C/126°F; surface temperature of whipped potatoes, 56°C/133°F; internal temperature of whipped potatoes, 60°C/140°F;

preservice holding time, 60 minutes). No statistically significant change was found in the number of *B. cereus* in whipped potatoes before or after preservice holding. Although the surface temperature (56°C/133°F) of the product was below the maximum temperature (59°C/138°F) for spore germination, the temperature was never low enough for growth of vegetative cells (Snyder, 1982).

Commissary Foodservice Systems

Table 7 summarizes the results of studies dealing with the microbial quality of menu items produced in actual and simulated commissary foodservice systems.

Actual conditions. The microbial quality of spaghetti and chili during various stages of food product flow in a school foodservice system was investigated by Cremer and Chipley (1977a). Increases in the microbial population appeared to be related to the position of the product in the assembly process or in the reheating ovens. The investigators indicated that both thorough cooking and reheating are important for the safety of spaghetti and chili products.

Cremer and Chipley (1977b) also studied the microbial quality of precooked frozen hamburger patties in the same school foodservice operation. A wide variety of microorganisms, including heat-sensitive species, was found in all samples. Differences in mean internal temperatures (74 to 81°C/165 to 178°F) were observed during reheating for service. Internal temperatures below 74°C/165°F were found in every replication. On the basis of their findings, the authors suggested that point of service is a critical area for control in foodservice systems using precooked frozen entrees since the primary heat treatment occurs at this point.

In a later study, Cremer and Chipley (1979) studied the microbial quality of meat loaf prepared in a commissary system that supplied meals to the elderly. Although microbial quality was good, variations were noted among replications. No coliforms could be detected following heating for assembly. However, small numbers of staphylococci were present in meat loaf with an internal temperature of 62°C/144°F or less. To ensure the safety of this product, foodservice operators should, according to the authors, thoroughly cook meat prior to assembly, use good foodservice practices to prevent recontamination during refrigerated storage, and thoroughly reheat meat loaves before assembly.

More recently, Brown et al. (1982) studied various foodservice conditions, procedures, and practices that could affect the safety of food served in school foodservice systems. Twenty entrees were selected; all included potentially hazardous foods. Wide ranges were reported for time and temperature during preparation, transportation, and service of the menu items. The aerobic plate count for five entrees was above 100,000 CFU/g. Counts for the remaining fifteen entrees were low. Two entrees held between 7°C/45°F and 60°C/140°F for almost 2 hours were among the entrees with low aerobic plate counts. Based on these findings, the authors were unable to establish a clear relationship between the number of microorganisms and the internal temperature of food products during preparation, transportation, and service.

Simulated conditions. Tuomi et al. (1974a) simulated the practices of school kitchens in handling precooked, chilled, ground beef gravy to determine if such practices were likely to contribute to foodborne illness. After gravy was heated in a compartment steamer for 35 minutes, the highest temperature re-

ported was 58°C/137°F for gravy with an initial temperature of 18°C/65°F, and 53°C/127°F for gravy with an initial temperature of 8°C/46°F. *C. perfringens* was not isolated from any samples, but some samples contained coagulase-positive staphylococci. Although uniform heating time is usually recommended for chilled food served in school foodservices, data from this study indicate that heating a menu item for a stated period of time does not guarantee that the desired temperature will be reached.

In another laboratory study, Tuomi et al. (1974b) simulated handling practices in school foodservice systems. Ground beef gravy was the menu item selected, and *C. perfringens* was the microorganism studied. Gravy proved to be a good growth medium during the cooling process when the temperature was near the upper range for growth of *C. perfringens*, and the inoculum was from a culture in the logarithmic growth phase. However, when gravy was inoculated with *C. perfringens* in the logarithmic growth phase and then heated to 74°C/165°F, no viable cells of this organism were found, although spores would have survived to pose a later challenge.

Al-Obaidy et al. (1983) found that the temperature of spaghetti with meat sauce (approximately 40 portions) prepared according to a formulation developed by the NC-120 committee and held on a steam table decreased from 74°C/165°F to 66°C/151°F in approximately 30 minutes. Aerobic plate counts before and after 90 minutes at 66°C/151°F were less than 2,000 microorganisms per gram. After refrigeration for 24 hours and subsequent microwave reheating, the portions exhibited two- to three-fold increases in aerobic plate counts; a four- to five-fold increase was observed after a 4-week freezer storage period and microwave reheating. Although plate counts were

Table 7
Microbiological Quality of Menu Items Processed under Actual and Simulated Conditions in Commissary Foodservice Systems

Product	Final heating time temperature ^a	Indicator of micro- biological quality (organism or test)	Colony-forming units per gram (CFU/g)	Reference
Actual Conditions				
Spaghetti	20 to 25 minutes 94 to 201°F	Aerobic plate count Coliform Clostridia Staphylococci	1,000 to 1,480 50 to 80 ^b 150 to 370 10 to 20 ^b	Cremer and Chipley (1977a)
Chili	23 to 35 minutes 100 to 208°F	Aerobic plate count Coliform Clostridia Staphylococci	1,100 to 1,200 65 to 75 ^b 190 to 210 10 to 20 ^b	
Hamburger patties	25 to 30 minutes 151 to 192°F	Aerobic plate count Coliform Clostridia Staphylococci	1,270 to 1,540 20 to 33 ^b 300 to 480 40 to 75 ^b	Cremer and Chipley (1977b)
Meat loaf	30 to 105 minutes 120 to 210°F	Aerobic plate count Coliform Clostridia Staphylococci	200 to 400 0 80 to 130 20 to 50 ^b	Cremer and Chipley (1979)
20 entree items	variable variable	Aerobic plate count	≥ 100,000 for 5 entrees ^d	Brown et al. (1982)
Simulated Conditions				
Ground beef gravy	20,35 minutes 85 to 137°F ^c	Aerobic plate count <i>Clostridium perfringens</i> Coagulase-positive staphylococci	640 to 820 0 Few	Tuomi et al. (1974a)
Ground beef gravy	variable 165°F	<i>Clostridium perfringens</i> inoculum (1.4 x 10 ⁴ cells/g)	0	Tuomi et al. (1974b)

^a Temperature of product given as range unless indicated otherwise.

^b Expressed as colony-forming units per 10 grams of product.

^c Temperature and results represent values for beef gravy held at 82°F (unrefrigerated) prior to the final heat treatment.

^d Sampling point not given.

not dangerously high, they indicated that microbial growth was possible during storage and that post-holding contamination could contribute to elevated plate counts.

The post-cooking contaminants *E. coli.*, *Salmonella enteritidis*, *Salmonella typhimurium*, *S. aureus*, and *C. perfringens* were grown as broth cultures and applied to the surfaces of foods (Maxcy, 1976). Surface-inoculated meat loaf and peas were held at 50°C/122°F or

60°C/140°F for up to 2 hours. Survival of surface inocula was attributed to surface evaporation cooling the lodgement of bacteria. Covering food with a polyethylene film retarded surface evaporation and increased destruction of surface contaminants. Commissary foodservice systems in which prolonged holding of uncovered cooked foods occurs increase the potential hazards originating from microbial contaminants.

Comparisons among Foodservice Systems

During the 1970s, a number of investigators studied the effects of different foodservice systems on the microbial quality of menu items. Results under actual operating conditions were reported by Catering Research Unit, University of Leeds (1970) and Avens et al. (1978). In the Catering Research Unit study,

the number of microorganisms present in ten menu items was similar when the items were prepared either in a cook/freeze foodservice system or a conventional system. Avens et al. (1978) studied four school-lunch delivery systems: conventional, satellite (hot, bulk transport), satellite (chilled transport), and cook/freeze. No statistically significant differences were found in the aerobic plate counts among the four delivery systems.

Laboratory simulations of foodservice operations were reported by Zallen et al. (1975), Bobeng and David (1978b), and Norwell (1978). Zallen et al. (1975) studied the effects of different handling treatments (refrigeration, nominal cooking, and freeze/thaw) on the microbial quality of beef loaf. After each handling treatment, beef loaves were refrigerated at 0°C/32°F or 6°C/43°F for 0 (4 hours), 1, 2, 4, 7, or 9 days. Storage temperature had no observable effect on the fate of the microflora surviving from different handling treatments over a 9-day storage period. Low plate counts of ≤ 100 CFU/g were apparently achieved by a combination of cooking and reheating, followed by handling procedures that kept post-cooking contamination to a minimum. This work shows the level of microbial control that may be attained. Zallen and coauthors attributed changes in the eating quality of beef loaf to autoxidation of lipids rather than to the microbial growth pattern in the loaves.

The microbial quality of beef loaves produced in simulated cook/chill, cook/freeze, and conventional foodservice systems was studied by Bobeng and David (1978b). An initial heat treatment of 60°C/140°F destroyed almost all of the bacteria present in the raw product. The bacterial counts remained exceedingly low for loaves prepared in any of the foodservice systems studied.

Norwell (1978), simulating the same foodservice systems as Bobeng and David, found bacterial counts for beef loaves produced in the cook/freeze system significantly

higher than those produced in the cook/chill and conventional systems. Although the differences were statistically significant, Norwell pointed out that these differences were probably not of public health importance under normal operating conditions.

This review of microbiological studies emphasizes that all types of foodservice systems need to protect against microbial contamination of

menu items. According to the studies reviewed, the microbial quality of menu items in foodservice systems is dependent upon a number of factors. These include type of food, quality of raw ingredients, batch size, type of equipment used for cooking, and position of menu items in foodservice equipment. Of major importance is the management of time and temperature relationships throughout all stages of food product flow in every foodservice system.

Nutrient Retention Studies

Foods are a complex mixture of inorganic, organic, and biochemical compounds; thus, it is not surprising that heat, oxygen, and shifts in pH can affect the nutrient quality. Harris and Karmas (1975) reported wide ranges in the loss of heat-labile nutrients: 0 to 40 percent of vitamin A; 0 to 3 percent of carotenes; 0 to 40 percent of vitamin D; 0 to 55 percent of tocopherols; 0 to 60 percent of biotin; 0 to 100 percent of folic acid; 0 to 95 percent of inositol; 0 to 50 percent of pantothenic acid; 0 to 40 percent of B₆; 0 to 80 percent of thiamin; 0 to 75 percent of riboflavin; 0 to 40 percent of lysine; and 0 to 20 percent of threonine. Time and temperature relationships as well as other conditions play an important role in the magnitude of the nutrient loss.

Nutrient loss has been studied during home preparation and during commercial processing. Engler and Bowers (1976) reviewed the stability of B vitamins in meat during both home and commercial storage and preparation. Lund (1979) recently summarized the effect of commercial processing on nutrient retention. He reported that

commercial canning of ten vegetables resulted in the following mean losses: 39 percent of vitamin A; 64 percent of ascorbic acid; 51 percent of biotin; 61 percent of folacin; 54 percent of vitamin B₆; 61 percent of pantothenic acid; 69 percent of thiamin; 55 percent of riboflavin; and 46 percent of niacin. Earlier, Fennema (1977) calculated vitamin losses in canned or frozen/boiled vegetables as compared with freshly cooked products. On the average, the vitamin A content of canned or frozen, cooked vegetables was 10 percent less than that of the freshly prepared products. However, losses of thiamin, riboflavin, niacin, and ascorbic acid in canned vegetable solids averaged 67, 42, 49, and 51 percent, respectively, while losses of these nutrients in frozen, cooked products were 20, 24, 24, and 26 percent, respectively. Comparable trends in retention were calculated for vitamins in frozen, unthawed fruit versus canned fruit, although losses of vitamin A activity were higher in fruits than in vegetables. In general, retention of vitamins appears to be considerably higher in cooked, frozen products than in canned.

More recently, model systems have been used to quantitate reaction constants for nutrients during processing (see page 25). Fewer studies have dealt specifically with nutrient losses using the time and temperature relationships found in foodservice systems. However, if reaction rates are similar to those found in previous studies, extrapolation of data should allow for nutrient loss prediction.

Macronutrients

The effect of the method of cooking meat on cooking losses, i.e., fat and moisture, is well documented. Janicki and Appledorf (1974) reported that not only did the amount of fat decrease in ground beef patties that were broiled, grill-fried, or cooked by microwave, but also the ratio of unsaturated to saturated fatty acids significantly increased. Moreover, cholesterol was significantly ($p \leq 0.05$) reduced in all the ground beef patties except those cooked by microwave. Troepfer and coworkers (1955) found steaks cooked on the griddle had less drip, and, therefore, more protein than cuts of meat cooked by moist-heat methods of cooking.

According to data gathered in 1970 by the staff of the Catering Research Unit of the University of Leeds and cited by Livingston et al. (1973), the cook/freeze system improved lysine retention since there was less protein damage than from conventional hospital foodservice preparation. Livingston et al. pointed out that foodservice cooking processes in which individual pieces of meat, poultry, or fish are handled should have losses similar to those previously reported for domestic cooking.

Thiamin

The heat lability of thiamin has been well documented; thus, it often has been used as an indicator nutrient even though the food in question may not be a significant source of the vitamin.

Retention in cooked entrees. Kylen et al. (1964) compared thiamin retention in conventionally cooked beef roasts, pork roasts, beef loaves, and ham loaves with that in microwave-cooked ones. Thiamin retention did not differ significantly for beef roasts but was significantly higher for pork roasts cooked by microwave. Noble (1964, 1965) reported an average thiamin retention of 70 percent in broiled beef in contrast to 32 percent retention in braised beef. Average thiamin retention values were 72 percent and 42 percent in broiled and braised pork, respectively. Braising and simmering also were reported to result in different retention of thiamin in variety meats. Thiamin retained during braising varied from 34 percent for pork heart to 66 percent for sweet breads, while retention during simmering ranged from 30 percent for pork heart to 55 percent for sweet breads (Noble, 1970).

Roasting at a low temperature of approximately 93°C/199°F resulted in significantly greater ($p \leq 0.01$) losses of thiamin from turkey breast whether or not the breast was thawed before cooking (Engler and Bowers, 1975a). Thiamin averaged 0.58 µg/g of muscle (on a net-weight basis) for breasts roasted at 177°C/350°F and 0.48 µg/g for breasts roasted at 93°C/199°F.

Retention in reheated or held-hot entrees. Thiamin retention in frozen fried chicken did not differ significantly whether it was convection-heated, infrared-heated, steam-heated, or microwave-heated as long as the holding time was no more than 1½ hours (Ang et al., 1978). These retentions ranged from 88 to 92 percent. A significantly lower ($p \leq 0.05$) retention of 78 percent was found when the conventionally reheated chicken was held for 3 hours. Greater differences occurred for beef-soy patties (Table 8). Boyle and Funk (1972) reported that rib roasts cooked, chilled for 24 hours, and then sliced and reheated to 60°C/140°F had 68 percent thiamin retention as compared with 79 percent retention

in beef cooked at 60°C/140°F for 1½ hours and then sliced for serving.

Other researchers also have evaluated thiamin retention in mixed meat dishes. An 8-ounce portion of beef stew freshly prepared and held hot for 3 hours contained 0.141 mg thiamin (63 percent retention), while the same stew frozen and microwave-reheated contained 0.211 mg thiamin (95 percent retention) (Kahn and Livingston, 1970). Percent thiamin retentions were similar in held or microwave-reheated chicken a la king and shrimp Newburg, although the thiamin content of the freshly prepared chicken and shrimp was slightly lower than that of the beef stew. Using commercially prepared frozen products and assuming the thiamin content of the frozen samples to be 100, Kahn and Livingston also found that microwave-reheated beef stew, chicken a la king, and shrimp Newburg had thiamin retentions of 91 to 94 percent while infrared-reheated samples had slightly lower retentions ranging from 87 to 89 percent.

Thiamin retention in pot roast and gravy prepared by a conventional institutional method decreased significantly between 1½ and 3 hours of holding, while the thiamin in beans and franks decreased significantly after the first ½ hour of holding (Ang et al., 1975). To simulate cook/freeze convenience food handling systems, the researchers froze these same dishes and reheated them in a convection, infrared, or microwave oven or in a steamer. For all of these convenience methods, the thiamin retention for the pot roast and gravy was similar to that for conventional heating and holding for 3 hours. For beans and franks, retention was slightly higher (93 to 94 percent) reheated in a convection oven or by infrared than by a microwave oven or steamer (88 to 90 percent). In addition, frozen fish fillets handled conventionally retained 91 percent of their thiamin when the fillets were held 1½ hours. Retention decreased to 77 percent when

the fillets were held 3 hours. In contrast, fish fillets prepared with convenience food handling systems retained 89 to 96 percent.

In a series of studies on vitamin retention, spaghetti with meat sauce was prepared according to the formulation of the NC-120 committee using home or foodservice techniques (Table 9). In a home preparation cook/freeze/reheat system at Michigan State University, thiamin retention in spaghetti with meat sauce (all beef) was significantly affected by the reheating method; stovetop reheating resulted in 100 percent retention and microwave reheating in 70 percent retention (dry-weight basis). When a mixture

of 20 percent soy and 80 percent beef was used in the sauce, thiamin retentions were reversed: stovetop heating, 65 percent, and microwave, 95 percent (Zabik and Sawyer, 1982). Under hot-holding conditions in a simulated foodservice operation at Iowa, apparent thiamin retention was 77 percent following 90 minutes of holding at 79°C/174°F, and 78 percent after holding 3¾ hours at 72°C/162°F (wet-weight basis) (Mohd-Jan, 1983). A similar study at the University of Illinois showed that apparent thiamin retention after 90 minutes of holding at 65°C/149°F was 87 percent (wet-weight basis) or 83 percent (dry-weight basis).

Retention in stored entrees. Low temperatures can also affect thiamin retention. Kossovitsas et al. (1973) compared the thiamin retention in a chilled versus frozen food system. After 45 days, the chilled chicken a la king retained 84 percent thiamin while the frozen sample retained 77 percent.

Retention during processing steps. Lee et al. (1981) found that chicken breasts prepared in a simulated conventional foodservice retained 76 percent of the initial thiamin, on the "as-determined" base, following cooking. After the chicken breasts were held for 90 minutes at 64°C/147°F, a further loss of 7 percent occurred. Freezing the cooked chicken did not result in further thiamin loss, but an additional 4 to 7 percent was lost during reheating by microwave or conventional methods for a net retention of 60 to 64 percent. In a similar study with spaghetti, Khan et al. (1982) found that 6 to 13 percent of the thiamin in that entree was lost under the same holding and reheating conditions as used for the chicken; the net thiamin retention in the spaghetti was 87 to 94 percent. For both menu items, the thiamin loss during holding, freezing, and reheating was similar; the major loss of thiamin in chicken occurred during the cooking procedure.

In a cook/chill foodservice system with microwave reheating, Dahl and Matthews (1980a) reported that thiamin retention ranged from 70 to 75 percent in beef loaf after microwave reheating. Retention during the cook/chill portion of the foodservice system averaged 80 percent. In contrast, thiamin retention in beef stew was 36 percent after cooking, 27 percent after 27 hours of chilling, and still 27 percent after reheating to a serving temperature of 63°C/145°F by microwave (Nicholanco and Matthews, 1978).

Retention in vegetables. Several studies have also examined thiamin retention during the preparation of vegetables for foodservice. Erdman

Table 8
Nutrient Content of Beef-Soy Patties

Sample and treatment	Moisture	Retention*	
		Thiamin	Riboflavin
		(percent)	
Raw beef patties			
Frozen	45.8 ± 0.4	100.0a	100.0a
Frozen raw patties			
Convection-cooked, 7.5 to 8.5 minutes	49.2 ± 1.3	96.2ab	96.2ab
Convection-cooked, held ½ hour	47.8 ± 1.6	97.1ab	92.8bc
Convection-cooked, held 1½ hours	48.2 ± 1.7	98.1a	94.6ab
Convection-cooked, held 3 hours	45.6 ± 1.0	98.1a	86.4cd
Char-broiled patties			
Frozen	48.9 ± 0.5	96.2ab	92.3ab
Frozen char-broiled patties			
Convection-heated, 8 minutes, held ½ hour	47.7 ± 1.0	96.2ab	95.0ab
Infrared-heated, 7 minutes, held ½ hour	41.6 ± 1.8	80.0c	81.0d
Steam-heated, 7 to 10 minutes, held ½ hour	54.2 ± 1.6	89.5b	91.4bc
Microwave-heated, 7 minutes, held ½ hour	44.9 ± 1.4	99.1a	90.4bc

SOURCE: Ang et al. (1978).

NOTE: Data represents average and standard deviation of six replicate preparations.

* Average retention based on frozen raw beef as 100 percent. Means followed by the same letter are not significantly different at the 5 percent level.

Table 9
Vitamin Retention in Spaghetti with Meat Sauce

State and product	Percent retention		
	Ascorbic acid	Thiamin	Riboflavin
Michigan			
Freshly prepared (all beef)	100 ^a	100 ^a	
Frozen, reheat stove	24	100	
Frozen, reheat microwave	21	70	
Freshly prepared (20% soy, 80% beef)	100	100	
Frozen, reheat stove	16	65	
Frozen, reheat microwave	19	95	
Iowa			
Freshly prepared (all beef)	100 ^b	100 ^b	
Held 90 minutes at 79°C/174°F	59	77	
Held 3¾ hours at 72°C/162°F	73	78	
Illinois			
Freshly prepared (all beef)		100 ^{a,b}	100 ^{a,b}
Held 90 minutes at 65°C/149°F		83 ^a , 87 ^b	99 ^a , 104 ^b

SOURCE: NC-120 regional project. For Michigan results, see Zabik and Sawyer (1982); for Iowa results, see Christensen (1981) and Mohd-Jan (1983); for Illinois results, see Klein et al. (1982).

^a Retention on dry-weight basis.

^b Retention on wet-weight basis.

(1979) cited early data of Munsell et al. on large-scale cooking of cabbage. Cabbage boiled until done retained 41 percent thiamin. The loss was evidently all due to leaching because the cabbage and cooking water together had a thiamin retention exceeding 100 percent. Steaming cabbage resulted in a thiamin retention of 85 to 88 percent.

Kahn and Livingston (1970) reported that freshly prepared, frozen peas in cream sauce that were reheated by microwave or infrared retained 92 to 93 percent of thiamin, while those reheated by immersion retained 87 percent thiamin. Peas in cream sauce cooked fresh and held for 1 to 3 hours at 82°C/180°F retained 76 to 87 percent thiamin. When compared with the unheated, commercially frozen peas in cream sauce, microwave-heated, commercially frozen peas in cream sauce retained 92 percent thiamin, while those reheated by infrared retained 89 percent.

Ang et al. (1975) reported that cook/freeze foodservice handling resulted in 87 to 92 percent thiamin in mashed potatoes. Thiamin retention in conventionally prepared mashed potatoes varied from 97 percent for ½-hour holding to 82 percent for 3-hours holding. Retention in carrots as well as in peas and onions showed similar trends, although percentages of thiamin retention were slightly higher.

Riboflavin

Riboflavin retention in meat is generally higher than thiamin retention. Noble (1964, 1965) reported riboflavin retentions ranging from 81 to 91 percent for broiled pork and beef, while braising gave riboflavin retentions of 73 and 68 percent for pork and beef, respectively. Riboflavin retention in braised variety meats ranged from 61 percent for sweet breads to 72 percent for

pork heart, and simmered variety meats had riboflavin retentions ranging from 46 percent for beef kidney to 72 percent for lamb heart (Noble, 1970). Riboflavin retention patterns in reheated frozen fried chicken were similar to that reported for thiamin (Ang et al., 1978).

Ang et al. (1975) also evaluated riboflavin retention in several institutionally prepared foods. Although some variation occurred, mashed potatoes, beans and franks, and peas and onions retained over 90 percent of their riboflavin when prepared in conventional or cook/freeze style foodservice systems. Riboflavin retention for pot roast and gravy ranged from 86 to 89 percent after reheating in a steamer or by microwave and fell to 82 percent after conventional foodservice preparation and 3 hours of holding. All other riboflavin retention values were above 90 percent.

After preparing spaghetti with meat sauce and holding it 90 minutes at 65°C/149°F, Klein et al. (1982) found little or no riboflavin loss (Table 9).

B₆

Engler and Bowers (1975b) studied vitamin B₆ retention during reheating of roasted turkey that contained 4.30 µg/g of B₆. After the turkey was held for 60 minutes at 96°C/205°F, the value was 3.61. Other turkeys were held chilled (6°C/43°F) for approximately 24 hours and then reheated. Values for turkey reheated in electric or microwave ovens were 3.69 and 3.79 µg/g, respectively.

Ascorbic Acid

Ascorbic acid retention in spaghetti with an all-beef sauce (Table 9) in a cook/freeze/reheat home preparation system was slightly higher with stovetop reheating than with microwave reheating, while the opposite was true for spaghetti with a 20 percent soy and 80 percent beef sauce (Table 9; Zabik and

Sawyer, 1982). After spaghetti with an all-beef sauce was hot-held in a simulated foodservice operation, 59 percent of the ascorbic acid was retained after 1½ hours at 79°C/174°F (Mohd-Jan, 1983), whereas 73 percent was retained after 3¼ hours at 72°C/162°F (Christensen, 1981). Similar formulations for the menu items were used in both studies.

The lability of ascorbic acid is well documented in home and commercial processing (Lund, 1979; Erdman, 1979; Erdman and Klein, 1982; Klein, 1982). Using a conventional foodservice system, Ang et al. (1975) reported that freshly prepared mashed potatoes retained 66 percent ascorbic acid after ½ hour and 40 percent after 3 hours of holding. Four cook/freeze convenience systems gave no better retention after reheating and holding for ½ hour: steamer, 41 percent; convection oven, 36 percent; infrared or microwave, 24 percent.

β-Carotene

Ang et al. (1975) also quantitated β-carotene retention during conventional and cook/freeze/reheat preparation of carrots. Conventionally handled carrots retained 88 to 95 percent β-carotene, while carrots prepared by freezing and the four reheat methods listed above retained from 92 to 95 percent β-carotene.

As this review of studies on nutrient quality indicates, nutrient retention in foodservice systems is dependent upon a variety of factors. Livingston and Chang (1979) summarized these as: (1) nutrient type; (2) type, quantity, and configuration of food; (3) container used; (4) heating rate; and (5) handling during heating, including exposure to air and light.

Sensory Quality Studies

The sensory quality of food is measured by the response of consumers to certain attributes such as appearance, flavor, texture, and temperature. Sensory quality is related to the condition of food when it enters a foodservice system and to the degree of control of the procedures for food processing and holding within a system. The times and temperatures used for storage and processing, as well as packaging materials, are conditions commonly used in the food industry to determine and control the rate of deterioration. Additionally, the standardization of system procedures, including standardized purchase criteria, preparation methods, formulations, and size and shape of portioned food, are essential to maintaining consistent sensory quality at the point of service in foodservice operations.

Research on the effects of time and temperature on the sensory quality of food during the various process steps at service is limited, as can be seen from the studies reviewed below. As a result, data and conclusions about the sensory quality of food frequently are taken from other investigations in food science and microbiology and then applied tentatively to the foodservice field. Extensive research does exist on the sensory qualities of foods prepared on a small or home scale, but the importance of testing such information in an actual or simulated foodservice setting cannot be overemphasized because of the complex, interactive nature of food product flow patterns in various commercial and institutional settings.

Sensory Quality after Hot-Holding

Hot-holding or warm-holding of food is accomplished through the use of a stationary steam table or movable cart. Of all the possible stresses on sensory quality during meal distribution, hot-holding has caused the greatest concern. In fact, hot-holding has been cited as a very "effective" means of destroying the sensory quality of food products that have been prepared after a careful choice of raw materials and processing and storage conditions (Bengtsson and Dagersbog, 1978).

Sensory quality losses through hot-holding can be reduced, however, by proper control of the environment and temperature. The most effective measure is to reduce the time between preparation and serving to a practical minimum (Bengtsson and Dagersbog, 1978). Measures recommended by Karlstrom and Jonsson (1977) include the choice of proper cooking method and the regulation of time, temperature, and air humidity.

Length of holding. Bengtsson and Dagersbog (1978) determined that more than 2 hours of hot-holding greatly reduced the sensory quality of beef slices and patties in a cook/freeze system. Differences noted in the beef products after precooking were not noticeable after 2 hours of hot-holding. Hill et al. (1977) affirmed that hot-holding is destructive to vegetable quality and recommended that vegetables be consumed directly following cooking and not be subjected to more than 30 minutes hot-holding. Paulus et al. (1978) evaluated the sen-

sory quality of meat entrees after hot-holding. Meat entrees evaluated included sauerbraten, chicken fricassee, meat loaf, beef goulash, and fried sausage. The researchers concluded that meat entrees could be held hot at least 3 hours without major decreases in sensory quality. Paulus et al. (1979) also indicated a steady decline in the quality of food products other than meat held for up to 5 hours.

Type of food held. Karlstrom and Jonsson (1977) stated that certain sensory attributes suffer more than other sensory attributes during hot-holding depending on the type of food. According to these authors, the sensory attributes of potatoes are most affected by hot-holding, followed by those of fish and meat. Hill et al. (1977) reported that creamed potatoes prepared from fresh potatoes deteriorated in flavor even after only 15 minutes of hot storage. Hansson et al. (1972) determined that hot-holding had the most deleterious effect on flavor. The flavor of potatoes was the most affected, followed by that of peas, fish-cakes, and hamburgers.

Effect of Equipment on Sensory Quality

Distribution equipment. Rambech (1979) concluded that the physical transportation and in-transit storage of foods held hot with presently accepted meal distribution systems should not create any sensory quality problems. Rambech stated that the problems that do occur are, with very few exceptions, the result of human factors. In contrast, however, Glew (1973) concluded that the use of heated transport or hot cupboards in any foodservice system must result in palatability losses.

Delivery systems. In a recent study, Cardello (1982) compared the effect of plating systems on sensory quality of food in five hospital foodservice delivery systems. Two hot-plating and three cold-plating systems were studied. Each system

was tested for 10 days with 68 individual food and beverage items; 72 percent were hot entrees and 28 percent were cold entrees. The entrees were evaluated for appearance, temperature, flavor, texture, and overall quality by hospital patients in a medical surgical ward. Results indicated that the major difference among delivery systems was between hot-plating and cold-plating systems. Food served from hot-plating systems was preferred by patients; reheating previously cooked and frozen food had adverse effects on the quality of the food at point of service.

Reheat equipment. Sensory quality can be affected by complications that result from inadequate design of reheat equipment. One complication is uneven temperature distribution during reheating or hot-holding. Product areas may be overheated at the edges, while interiors may not have been reheated to appropriate temperatures for optimal sensory quality. As a result, sensory quality may not be consistent within and among batches. Heat pipes used in foodservice processing equipment were shown to be an effective method of decreasing the variation in product temperature (Milson and Kirk, 1980).

Bengtsson (1979) listed five complications of inadequate reheat equipment design that can affect sensory quality:

- Food may be overheated. Significant losses of sensory quality then occur because of excessive surface drying, moisture loss, decreased yield, and color and texture changes.
- Food may be underheated. The result is less-than-optimal temperatures at service, which may lower sensory acceptability.
- Uneven heating gives a combination of sensory losses similar to over- and under-heating.
- Foods reheated in polyethylene or paperboard packaging may become overheated causing deformation, melting, or even burning or charring of the packaging material. The accom-

panying release of volatiles may be detrimental to the sensory quality of the food.

- Accumulated food debris, fats, and juices on heating surfaces become oxidized or pyrolyzed, and volatiles from these materials will result in off-flavors in the food being reheated.

Temperature and Sensory Acceptability

The temperature of food is well recognized as a major factor in sensory acceptance of the food (Dahl, 1982). To serve hot foods hot ($\geq 60^{\circ}\text{C}/140^{\circ}\text{F}$) and cold foods cold ($\leq 7^{\circ}\text{C}/45^{\circ}\text{F}$) is thus a goal of and a challenge to foodservice personnel. Part of the challenge is that the serving temperatures preferred by consumers vary among types of hot foods (coffee versus stew) and among types of cold foods (milk versus ice cream). Temperature preferences of consumers also vary.

Blaker et al. (1961) reported the following temperature ranges were preferred for four classes of foods served hot: soup, 63 to 66°C/145 to 151°F; potatoes and vegetables, 60 to 63°C/140 to 145°F; entrees, 60 to 63°C/140 to 145°F; and beverages, 63 to 66°C/145 to 151°F.

In a Swedish study, Jonsson et al. (1977) indicated that the temperatures preferred by healthy subjects varied over a relatively wide range. Examples of these ranges for selected products are 63 to 75°C/145 to 167°F for potatoes, 60 to 76°C/140 to 169°F for meat balls, and 59 to 69°C/138 to 156°F for pea soup. Responses of surgical patients served the regular "house" diet in a general hospital also indicated that a wide range of temperatures was acceptable for selected types of products: 46 to 79°C/115 to 174°F for potatoes, 49 to 79°C/120 to 174°F for vegetables, and 38 to 71°C/100 to 160°F for meats (Thompson and Johnson, 1963).

Research conducted at Iowa State University using a single entree item—a ground beef and tomato sauce mixture—indicated that the

preferred eating temperature may be dependent upon the age of the consumer. Third-grade children ($n = 49$) preferred the ground beef mixture served at 49°C/120°F when offered the mixture at 49/120, 54/129, and 60°C/140°F (Norris, 1981; Morrison, 1982). Adults age 20 to 59 ($n = 60$) preferred 60°C/140°F when the mixture was offered at 49/120, 54/129, and 60°C/140°F or 54/129, 60/140, and 66°C/151°F (Oporum, 1981; Baltzer, 1982). Adults age 65 and over ($n = 49$) preferred 66°C/151°F when offered the same temperature choices as the adults age 20 to 59 (Peterson, 1981; Gross, 1983). Many individuals considered more than one temperature to be "just right," the designation used to indicate the preferred temperature.

Effect of Foodservice System on Sensory Quality

According to Matthews (1977), food prepared in ready-prepared foodservice systems (cook/chill and cook/freeze) and reheated prior to service is less desirable than food prepared in conventional foodservice systems. Zallen et al. (1975) reported that sensory scores of freshly prepared beef loaves were significantly ($p \leq 0.01$) higher than those for similar products stored and reheated.

Bobeng and David (1978b) reported that sensory scores for color of meat and uniformity of color were significantly different for conventionally prepared beef loaf than for beef loaf prepared in cook/chill or cook/freeze systems. They attributed the difference to the second-heat process in cook/chill and cook/freeze systems. They indicated that beef loaves were darker and more streaked (nonuniform) in these systems than beef loaves prepared by the conventional system. The researchers also found that taste panel scores for overall acceptability were significantly ($p \leq 0.05$)

greater for beef loaves prepared in a conventional system than for those prepared in cook/chill and cook/freeze systems. Mean scores for overall acceptability were: conventional, 5.30; cook/chill, 3.73; and cook/freeze, 2.78. Possible scores were from 1.00, very unacceptable, to 7.00, very acceptable. Flavor predominated in predicting overall acceptability of beef loaves. On the other hand, Glew (1968) concluded that precooked, reheated food was as acceptable to patients as food cooked by traditional methods involving hot-holding.

Sensory quality of scrambled eggs and beef patties was evaluated after heating in institutional microwave and convection ovens (Cremer, 1982). Scores for all characteristics evaluated were significantly ($p \leq 0.01$) higher for eggs heated in the microwave rather than the convection oven. For beef patties, however, scores were higher for all characteristics and significantly ($p \leq 0.01$) higher for appearance, flavor, and general acceptability after heating in the convection rather than the microwave oven.

Beef loaf, mashed potatoes, and peas were prepared in a simulated hospital cook/chill foodservice by Sawyer et al. (1983). The purpose of the study was to evaluate the effect of different reheat systems on the sensory quality of food at point of service. For each product, four trials were performed using conduction, convection, and microwave radiation subsystems. Panelists' scores showed there was a clear preference for beef loaf reheated by conduction and for peas reheated by microwave radiation. Moreover, Sawyer et al. found that microwave radiation resulted in the highest rating overall for satisfaction for two of the three foods reheated. Their findings contrast with work done by Ferguson (1981), who identified specific flavor deficiencies of microwave-cooked products such as uncooked starch, low salt intensity, and a pronounced flavor of fats and oils.

European foodservice systems often reheat food and hold it hot until service. Reheat subsystems used in the United States also demonstrate such capabilities. For example, an integral heating module such as the 3M reheat system has a hold cycle of 12 minutes in which food temperature is to be held at 60°C/140°F or greater. Paulus (1979) recommended that hot-holding periods after reheat be limited to 30 minutes to retain optimal sensory qualities in the food.

In several studies by Cremer and Chipley, the sensory quality of food prepared in actual foodservice operations has been evaluated. In one study, spaghetti and chili were prepared from basic ingredients and processed through a commissary system with chilled food transportation and heating in convection ovens (Cremer and Chipley, 1977a). In another study, precooked frozen hamburger patties were prepared in a commissary system with chilled food transportation and heating in convection ovens (Cremer and Chipley, 1977b). In another study, scrambled eggs and roast beef were prepared in a ready-prepared system with chilled storage and heating in microwave ovens (Cremer and Chipley, 1980a, b). In yet another study, meat loaf was prepared in a commissary system with food transported hot (Cremer and Chipley, 1979). A hedonic 9-point scale was used in all four studies. Mean scores for the various sensory characteristics scored ranged from 5.9 to 6.8 for spaghetti, 6.3 to 7.4 for chili, 5.4 and 6.5 for hamburger patties, 6.3 to 8.1 for scrambled eggs, 6.9 to 7.5 for roast beef, and 6.2 to 7.2 for meat loaf.

A series of studies conducted by members of the NC-120 committee helped to identify problem areas in reproducibly measuring specific qualities of a menu item using sensory evaluation by trained taste panels. In these studies, the same formulation of spaghetti with meat sauce was used by investigators at different experiment stations in the

North Central Region; preparation techniques, either home or foodservice, also were standardized as much as possible. In addition, a common scoring procedure (an unstructured, 14-point scale with verbal anchors, see opposite) was used for the evaluation by trained taste panels. Sensory scores for firmness were compared with instrumental measurements of spaghetti texture using the Instron Universal Testing Machine or Allo-Kramer shear press. Home and foodservice preparation, holding, storing, and reheating methods were examined; quantities of food prepared were adjusted for the methods used. The results are given in Tables 10 through 17.

In general, the color, the intensity of spice, beef, or off-flavors, and the blending of flavors in the spaghetti with meat sauce were not greatly affected by the post-cooking treatment. However, textural properties of the spaghetti (clumping, firmness, and chewiness) were changed significantly, with these qualities being the highest in the freshly prepared product, as anticipated. Characteristics of the meat sauce such as surface appearance (moistness), mouthfeel dryness, fat separation or greasiness, and meat texture were affected to a lesser extent than characteristics of the spaghetti portion of the dish. Freezing the pasta produced the most adverse effects, as would be expected in a gelatinized starch product. The Instron measurements of spaghetti texture (using either the multiblade shear cell or the Ottawa Texture Test System) correlated with the sensory scores (Tables 15 and 16). Textural changes measured with the Allo-Kramer shear press (Table 17) were not significant, since the observed differences among treatments were small.

The results of the NC-120 regional project studies indicate that sensory properties of foods in actual foodservice operation are comparable to those observed in studies of simulated systems. Specific char-

Sensory Characteristics and Scale Anchors Used to Evaluate Sensory Quality of Spaghetti with Meat Sauce in NC-120 Regional Project

Characteristic	Scale anchor and score
Appearance	
Color	1 = red orange, 14 = brownish red
Moistness	1 = looks dry, 14 = looks moist
Fat separation	1 = little separation, 14 = much separation
Spaghetti clumping	1 = strands clump together, 14 = individual strands apparent
Flavor	
Intensity spice flavor	1 = weak, 14 = strong
Blended flavor	1 = unblended, 14 = blended
Intensity beef flavor	1 = weak, 14 = strong
Intensity off-flavor	1 = little off-flavor, 14 = strong off-flavor
Mouthfeel	
Dryness	1 = very wet, 14 = very dry
Greasiness	1 = not greasy, 14 = very greasy
Texture	
Spaghetti firmness	1 = extremely soft, 14 = extremely firm
Spaghetti chewiness	1 = extremely tender, 14 = extremely chewy
Meat chewiness	1 = crumbly, 14 = cohesive

Table 10
Sensory Data for Freshly Prepared Spaghetti and Spaghetti Held in a Simulated Hot-Holding System

Characteristic	Fresh	Held at 74°C/165°F for		
		45 minutes	90 minutes	180 minutes
Color	4.8	6.6	6.7	8.9
Moistness	12.2	8.6	7.4	5.3
Fat separation	7.0	5.8	4.0	3.6
Spaghetti clumping	11.5	9.1	7.7	6.9
Intensity spice flavor	7.4	7.3	7.3	6.8
Blended flavor	5.9	8.3	8.2	9.0
Intensity beef flavor	6.6	8.4	8.6	8.5
Intensity off-flavor	5.5	5.2	4.2	5.0
Dryness	2.9	4.7	6.2	6.8
Greasiness	7.2	5.5	6.3	6.1
Spaghetti firmness	11.0	8.3	7.5	5.2
Spaghetti chewiness	11.6	8.2	7.1	4.4
Meat chewiness	10.0	8.6	8.5	7.7

SOURCE: Love and Love (1982). Study conducted at Iowa State University.

NOTE: Means are based on the evaluations of eight judges, four replications, using a 14-point scale (see above).

acteristics of menu items, such as their textural properties, are more sensitive to deterioration during procedures used for holding and reheating and thus could be used as quality indicators. Instrumental measurements of texture can be correlated with sensory scores and could provide more reproducible quantitation of quality change.

Training taste panels and developing a sensory instrument are fundamental to accurately measuring the sensory quality of foods. The results of the regional project studies suggest that a common scoring methodology can be developed and used at different research centers. Using the same procedures in multiple investigations would help in the validation of results and provide a broader base for comparison of time and temperature effects on food quality.

Table 11
Sensory Data for Freshly Prepared Spaghetti and Spaghetti Held Hot in a Conventional Foodservice System

Characteristic	Fresh	Held 90 minutes (65°C/149°F)
Color	4.0	3.3
Moistness	8.4	4.2
Fat separation	2.8	2.5
Spaghetti clumping	7.8	4.3
Intensity spice flavor	6.0	4.3
Blended flavor	7.5	6.8
Intensity beef flavor	6.0	5.8
Intensity off-flavor	0.9	2.1
Dryness	3.2	6.0
Greasiness	3.5	4.6
Spaghetti firmness	4.8	1.6
Spaghetti chewiness	4.9	2.0
Meat chewiness	5.0	3.6

SOURCE: Al-Obaidy et al. (1983). Study conducted at the University of Illinois at Urbana-Champaign.

NOTE: Means are based on evaluations of eight to ten judges, four replications, using a 14-point scale (see page 21).

Table 12
Sensory Data for Freshly Prepared and Frozen Spaghetti Using a Cook/Freeze System

Characteristic	Fresh	Frozen, with evenly spaced freeze-thaw cycles of			Frozen, with 5 immediate freeze-thaws then stored
		1	2	3	
Fat separation	8.9	9.7	8.7	8.5	8.3
Spaghetti clumping	10.2	6.0	6.6	5.8	5.8
Intensity spice flavor	8.7	5.4	5.1	5.1	5.2
Intensity off-flavor	3.2	4.3	4.7	6.1	5.0
Dryness	5.7	7.5	8.6	7.6	8.0
Greasiness	7.7	8.3	8.2	8.3	8.2
Spaghetti firmness	9.6	5.4	4.7	3.5	4.0

SOURCE: Blomquist and Setser (1982). Study conducted at Kansas State University.

NOTE: Means are based on evaluations of eight judges, six replications, using a 14-point scale (see page 21). Freezer storage time was five weeks.

Table 13
Sensory Data for Freshly Prepared and Reheated Spaghetti Using Home Preparation Techniques

Characteristic	Fresh		Frozen/stove reheat		Frozen/micro-wave reheat	
	All beef	20% soy	All beef	20% soy	All beef	20% soy
Color	5.2	6.2	5.5	6.0	6.0	5.7
Moistness	11.7	7.5	8.3	7.9	6.6	5.8
Fat separation	5.6	4.7	5.3	5.3	4.9	4.2
Spaghetti clumping	11.6	10.3	7.7	8.1	6.8	6.4
Intensity spice flavor	8.2	7.5	7.3	6.2	7.5	6.6
Blended spice flavor	10.5	9.4	9.5	9.2	9.6	8.4
Intensity beef flavor	6.4	7.2	7.7	7.5	7.9	7.3
Intensity off-flavor	2.9	4.6	4.7	5.5	5.1	5.3
Dryness	4.4	6.5	6.5	7.3	7.8	8.5
Greasiness	5.7	5.3	6.1	5.4	5.9	4.6
Spaghetti firmness	6.0	6.3	5.4	4.8	6.2	5.7
Spaghetti chewiness	5.0	5.3	4.3	4.4	4.8	5.5
Meat chewiness	6.8	7.2	6.5	6.0	7.1	7.0

SOURCE: Zabik and Sawyer (1982). Study conducted at Michigan State University.

NOTE: Means are based on evaluations of eight judges, four replications, using a 14-point scale (see page 21). Spaghetti was made in batches of eight servings.

Table 14
Sensory Data for Spaghetti with Meat Sauce Reheated by Two Methods After Chill or Frozen Storage

Characteristic	Fresh	Convection oven				Microwave oven			
		Chilled 1 hour	Chilled 24 hours	Frozen 24 hours	Frozen, 24 hours; chilled, 24 hours	Chilled 1 hour	Chilled 24 hours	Frozen 24 hours	Frozen, 24 hours; chilled, 24 hours
Color	6.0	6.7	7.2	6.9	7.0	6.4	6.3	6.8	7.3
Moistness	11.2	7.3	7.2	6.3	6.8	8.3	9.1	7.2	5.6
Fat separation	5.1	6.8	5.3	5.6	6.6	6.2	6.9	7.4	7.6
Spaghetti clumping	11.4	8.9	8.4	8.5	8.8	8.9	9.0	7.7	6.0
Intensity spice flavor in sauce	8.1	7.6	7.2	6.4	7.3	7.6	6.9	7.3	7.0
Blending of flavors in sauce	9.5	8.8	9.4	9.3	9.1	9.1	8.9	8.9	9.2
Intensity spice flavor in meat	6.8	6.9	6.1	6.0	6.9	6.2	6.4	6.7	6.8
Intensity beef flavor	5.7	6.0	5.7	5.6	5.8	5.3	6.5	6.0	5.7
Intensity off-flavor	1.0	1.5	1.5	1.7	1.7	2.0	1.5	1.7	1.8
Dryness	4.7	5.9	6.5	7.1	7.2	5.7	6.3	6.3	7.4
Greasiness	5.6	6.8	6.6	6.8	7.2	6.9	7.5	7.3	7.9
Spaghetti firmness	9.2	7.1	6.1	5.0	5.5	7.4	7.3	7.1	6.6
Spaghetti chewiness	8.5	6.1	5.5	5.0	4.8	6.7	6.7	6.4	6.8
Meat chewiness	8.1	7.6	7.4	6.4	7.0	8.0	7.5	7.7	6.9

SOURCE: Cremer (1983). Study conducted at The Ohio State University.

NOTE: Means are based on evaluations of eight judges, four replications, using a 14-point scale (see page 21).

Table 15
Mean Scores for Spaghetti Firmness and Texture, Iowa

Sample	Sensory score for firmness ^a	Instrumental tests for texture	
		Multiblade shear ^b (kg)	Ottawa Texture Test System ^c (kg)
Experiment I			
Freshly prepared	11.0	8.8	—
Held 45 minutes ^d	8.3	6.2	—
Held 90 minutes ^d	7.5	5.3	—
Held 180 minutes ^d	5.2	3.9	—
Experiment II			
Pasta cooked 14 minutes, no product holding	12.4	7.3	23.4
Pasta cooked 15 minutes, held in sauce 60 minutes ^d	7.7	5.8	17.4
Pasta cooked 30 minutes, held in sauce 120 minutes ^d	3.2	4.4	12.2

SOURCE: Love and Love (1982). Study conducted at Iowa State University.

^a In Experiment I, means are based on evaluations of nine judges and three replications, using a 14-point scale, with 1 = extremely soft, 14 = extremely firm. Means in Experiment II are based on evaluations of eight judges and four replications, using the same 14-point scale.

^b Force needed to cut 10 strands of spaghetti; mean of three tests in Experiment I; mean of six tests in each of two replications in Experiment II. Instron crosshead speed = 200 mm/minute.

^c Force needed to extrude 100 grams through a perforated plate. Mean of three tests in each of two replications. Instron crosshead speed = 20 mm/minute.

^d Held at 74°C/165°F.

Table 16
Mean Scores for Spaghetti Firmness and Texture, Kansas

	Sensory score for firmness ^a	Ottawa Texture Test System ^b (kg)
Freshly prepared	9.6	63.4
Freeze-thaw cycle 1	5.4	55.4
3	4.7	54.4
5	3.5	56.6
Freeze-thaw cycle, 5 immediate	4.0	53.6

SOURCE: Blomquist and Setser (1982). Study conducted at Kansas State University.

^a Means are based on evaluations of eight judges, six replications, using a 14-point scale with 1 = extremely soft, 14 = extremely firm.

^b Force needed to extrude 100 grams through a perforated plate. Mean of two tests in each of three replications. Instron crosshead speed = 20 mm/minute.

Table 17
*Mean Scores for Spaghetti Firmness,
Chewiness, and Texture, Michigan*

	Sensory score* for		Allo-Kramer tenderness (lb/g)
	Firmness	Chewiness	
Freshly prepared			
All beef	6.0	5.0	0.62
20% soy	6.3	5.3	0.63
Frozen/reheat			
All beef			
Stovetop	5.4	4.3	0.67
Microwave	6.2	4.8	0.65
20% soy			
Stovetop	4.8	4.4	0.57
Microwave	5.7	5.5	0.56

SOURCE: Zabik and Sawyer (1982). Study conducted at Michigan State University.

* Means are based on evaluations of eight judges, four replications, using a 14-point scale with 1 = extremely soft or extremely tender, 14 = extremely firm or extremely chewy.

Approaches to Prediction of Food Quality

The food processing industry has developed a series of parameters that are used in the prediction of the quality of the final product. The use of prediction models for quality characteristics of foods following processing is relatively new and has only been applied to a few situations. The parameters generally describe the effects of factors such as the time and temperature of individual processing operations on specific characteristics of the food. The qualities that are most frequently assessed are the microbiological and nutritional components.

According to Lund (1977), most enzymes and microorganisms (vegetative cells and spores) are more easily destroyed by heat than are the sensory and nutritional qualities

of foods. For food processing operations, the thermal destruction of enzymes, microorganisms, nutrients, and sensory quality has been described in terms of D and z values (Lund 1975, 1977). The D value is the time it takes, at a given temperature, for the concentration of a given component (for example, a microorganism or a nutrient) to decrease by 90 percent. This parameter is comparable to the reaction rate constant, k , used in chemical kinetics. The z value is the temperature change ($^{\circ}\text{F}$) necessary to decrease the concentration of a component one order of magnitude (through one log cycle). The z value thus is a measure of the sensitivity of a component to thermal destruction. The D and z values are

used to determine the amount of heat treatment needed in a processing operation.

Another parameter, the Q_{10} value, is used to describe the increase in a reaction rate that occurs at some high-abuse temperature. Labuza and Riboh (1982) suggest that the Q_{10} value could be used to predict shelf life by extrapolating to lower temperatures.

The Arrhenius activation energy (E_a) is another means of expressing thermal resistance of a food component. The destruction of a nutrient, for example, can be described by the Arrhenius equation, which employs the E_a . The equation is a mathematical description of the temperature dependence of a given reaction (Lenz and Lund, 1980). By studying a reaction and measuring the rate at which it occurs at several high temperatures, one should be able to extrapolate to lower temperatures and predict the rate at lower temperatures. Labuza and Riboh (1982) cautioned, however, that the rate constant at high temperatures may be influenced by a variety of factors related to physical changes within a complex food system, thereby introducing error into the prediction. Nevertheless, the two researchers found that when fluctuating temperatures were used for shelf life storage testing, the Arrhenius model was in general agreement with actual measurements. They pointed out, therefore, that the values predicted by the Arrhenius equation might still be acceptable in the food industry despite the possibility of errors.

Lund (1977) found that the energy of activation for the destruction of most vitamins is approximately 20 to 30 Kcal/mol. The activation energy is generally much higher for the destruction of enzymes or microorganisms used as indicators of the adequacy of thermal processing. This fact implies that the destruction of enzymes and microorganisms occurs more rapidly at high temperatures than does the loss of nutrients. However, sensory quality is more affected by

temperature than nutritional quality. This then suggests that preservation of sensory quality of food products in the foodservice industry will result in good nutritional value also.

Prediction models are not widely used in the food processing indus-

try as yet. However, many researchers believe that these models have the potential for cutting the amount of time and testing needed for shelf life studies and for improvement of ultimate quality of food products.

Future Research Directions

The investigations summarized in this bulletin indicate that there are substantial gaps in our knowledge that make it difficult to predict quality changes during the procedures used in foodservice operations. Lund (1982) pointed out the need for quantitative data on changes in flavor, texture, and appearance of foods so that processes can be designed to maintain and improve product quality. The same observation can be made with respect to the need for data in the field of foodservice systems, with the addition of the necessity for determining nutritional, chemical, and microbial changes in foods.

To predict changes in food quality so that procedures and processes can be modified requires different types of information than currently exist. To determine reaction rates for a specific food component (i.e., a nutrient) or sensory characteristic, one must take measurements at several specified times during heating or holding at a number of temperatures. In addition, temperatures throughout the heat processing cavity of the equipment as well as numerous locations within the menu items must be known. The different types of equipment, the occurrence of fluctuating temperatures, and the variations in times and temperatures used in foodservice operations present an additional challenge. Moreover, the applicability of data obtained in model food systems to

real foodservice operations must be considered, although there is some indication that constants generated in model systems can be confirmed in actual systems, even at divergent temperatures (Labuza, 1980; Labuza and Riboh, 1982).

An example of the type of study that will contribute to the development of prediction models for use in the food industry is a study done by Snyder (1982). She developed a simulated foodservice holding system in which the temperature of food in an institutional-size pan could be monitored, and the temperature held constant for long holding periods. Although Snyder could not directly relate ascorbic acid losses during hot holding to the minor temperature changes noted within a pan of whipped potatoes, comparison with other studies under simulated operating conditions (Ang et al., 1975; Augustin et al., 1982) indicated a similar rate of loss. Snyder's study confirms that the type of processing used is probably not as important as the times and temperatures used in the operation.

Literature reports of quality changes in actual foodservice systems can provide some of the information necessary to design studies that will produce the quantitative data needed for prediction of quality changes in menu items during product flow. The HACCP concept can be used to delineate the times

and temperatures that are being used for various steps in different foodservice systems. Compilation of the times and temperatures being employed in actual situations will help confirm a realistic range of temperatures to be used in simulated studies of quality losses in foods.

Studies based on the times and temperatures actually being used in the foodservice industry will help to establish the models for conservation of nutritional and sensory qualities and for maintaining microbial and chemical safety of foods that are prepared by thermal processing in foodservice systems. These models would allow us to develop data bases for time and temperature relationships to food quality. These data bases could then be used in decision-making models, leading to more efficient and effective foodservice management.

It is only by conducting carefully designed research that we will derive the new knowledge necessary to advance our understanding of the interrelationships among food products, processes, resources, and management in foodservices. With this information and the development of prediction and decision-making models, we could make recommendations for the improvement of food quality in foodservice establishments.

References

- Al-Obaidy, H., Khan, M.A., and Klein, B.P. 1983. Total plate counts and sensory evaluation of spaghetti/meat sauce entree held hot on a cafeteria counter. Presented at IFT Annual Meeting, New Orleans, LA.
- Ang, C.Y.W., Chang, A.M., Frey, A.E., and Livingston, G.E. 1975. Effects of heating methods on vitamin retention in six fresh or frozen prepared food products. *J. Food Sci.* 40: 997.
- Ang, C.Y.W., Basillo, L.A., Cato, B.A., and Livingston, G.E. 1978. Riboflavin and thiamin retention in frozen beef-soy patties and frozen fried chicken heated by methods used in foodservice operations. *J. Food Sci.* 43: 1024.
- Augustin, J., Marousek, G.A., Artz, W.E., and Swanson, B.G. 1982. Vitamin retention during preparation and holding of mashed potatoes made from commercially dehydrated flakes and granules. *J. Food Sci.* 47: 274.
- Avens, J.S., Poduska, P.J., Schmidt, F.P., Jansen, G.R., and Harper, J.M. 1978. Food safety hazards associated with school food service delivery systems. *J. Food Sci.* 43: 453.
- Baltzer, L.E. 1982. Unpublished paper. Temperature preference of adults for ground beef mixture served hot. Iowa State University, Ames.
- Bauman, H.E. 1974. The HACCP concept and microbiological hazard categories. *Food Technol.* 28(9): 30.
- Benderwald, D.L. 1978. Comparison of infrared and convection thermal processing for physical property changes of selected meats. M.S. thesis, University of Missouri, Columbia.
- Bengtsson, N. and Dagersbog, H. 1978. Fried meat and meat patties — the influence of preparation and processing on quality and yield. In "How Ready Are Ready-to-Serve Foods?" K. Paulus (Ed.), p. 147. S. Karger, New York.
- Bengtsson, N. 1979. Catering equipment design and food quality. In "Advances in Catering Technology," G. Glew (Ed.), p. 121. Applied Science Publishers, Ltd., London.
- Blaker, G.G., Newcomer, J.L., and Ramsey, E. 1961. Holding temperatures needed to serve hot foods hot. *J. Am. Dietet. Assoc.* 38: 450.
- Blomquist, C. and Setser, C. 1982. Unpublished data. Kansas State University, Manhattan.
- Bobeng, B.J. and David, B.D. 1977. HACCP models for quality control of entree production in foodservice systems. *J. Food Prot.* 40: 632.
- Bobeng, B.J. and David, B.D. 1978a. I. Development of hazard analysis critical control point models. HACCP models for quality control of entree production in hospital foodservice systems. *J. Am. Dietet. Assoc.* 73: 524.
- Bobeng, B.J. and David, B.D., 1978b. II. Quality assessment of beef loaves utilizing HACCP models. *J. Am. Dietet. Assoc.* 73: 530.
- Boyle, M.A. and Funk, K. 1972. Thiamin in roast beef held by three methods. *J. Am. Dietet. Assoc.* 60: 398.
- Brown, D.F. and Twedt, R.M. 1972. Assessment of the sanitary effectiveness of holding temperatures on beef cooked at low temperature. *Appl. Microbiol.* 24: 599.
- Brown, N.E., McKinley, M.M., Aryan, K.L., and Hotzler, B.L. 1982. Conditions, procedures, and practices affecting safety of food in 10 school food service systems with satellites. *School Food Service Research Review* 6: 36.
- Bryan, F.L. and Kilpatrick, E.G. 1971. *Clostridium perfringens* related to roast beef cooking, storage, and contamination in a fast food service restaurant. *Am. J. Pub. Health* 61: 1869.
- Bryan, F.L. 1978. Factors that contribute to outbreaks of foodborne disease. *J. Food Prot.* 41: 816.
- Bryan, F.L., Seabold, K.A., Peterson, R.W., and Roberts, L.M. 1978. Time-temperature observations of food and equipment in airline catering operations. *J. Food Prot.* 41: 80.
- Bryan, F.L. 1981. Hazard analysis of food service operations. *Food Technol.* 35(2): 78.
- Bryan, F.L., Bartleson, C.A., and Christopherson, N. 1981. Hazard analyses, in reference to *Bacillus cereus*, of boiled and fried rice in Cantonese-style restaurants. *J. Food Prot.* 44: 500.
- Bryan, F.L., Bartleson, C.A., Sugi, M., Sakai, B., Miyashiro, L., Tsutsumi, S., and Chun, C. 1982. Hazard analyses of char siu and roast pork in Chinese restaurants and markets. *J. Food Prot.* 45: 422.
- Bunch, W.L., Matthews, M.E., and Marth, E.H. 1976. Hospital chill foodservice systems: acceptability and microbiological characteristics of beef-soy loaves when processed according to system procedures. *J. Food Sci.* 41: 1273.
- Bunch, W.L., Matthews, M.E., and Marth, E.H. 1977. Fate of *Staphylococcus aureus* in beef-soy loaves subjected to procedures used in hospital chill foodservice systems. *J. Food Sci.* 42: 565.
- Cardello, A. 1982. Patients' perceptions of meal acceptability. In "Hospital Patient Feeding Systems," p. 31. Nat. Acad. Press, Washington, D.C.
- Catering Research Unit, University of Leeds, UK. 1970. An experiment in hospital catering using the cook/freeze system. 40p.
- Christensen, J.M. 1981. Effects of hot-holding time on spaghetti firmness and ascorbic acid content of spaghetti and meat sauce. M.S. thesis, Iowa State University, Ames.
- Cremer, M.L. and Chipley, J.R. 1977a. Satellite food-service system assessment in terms of time and temperature conditions and microbiological and sensory quality of spaghetti and chili. *J. Food Sci.* 42: 225.
- Cremer, M.L. and Chipley, J.R. 1977b. Satellite food service system: time and temperature and microbiological and sensory quality of precooked frozen hamburger patties. *J. Food Prot.* 40: 603.
- Cremer, M.L. and Chipley, J.R. 1979. Time and temperature, microbiological and sensory quality of meat loaf in a commissary foodservice system transporting heated food. *J. Food Sci.* 44: 317.
- Cremer, M.L. and Chipley, J.R. 1980a. Hospital ready-prepared type food-service system: time and temperature conditions, sensory and microbiological quality of scrambled eggs. *J. Food Sci.* 45: 1422.
- Cremer, M.L. and Chipley, J.R. 1980b. Time and temperature, microbiological, and sensory assessment of roast beef in a hospital foodservice system. *J. Food Sci.* 45: 1472.
- Cremer, M.L. 1981. Microwave heating of scrambled eggs in a hospital food-service system. *J. Food Sci.* 46: 1573.

- Cremer, M.L. 1982. Sensory quality and energy use for scrambled eggs and beef patties heated in institutional microwave and convection ovens. *J. Food Sci.* 47: 871.
- Cremer, M.L. 1983. Unpublished data. The Ohio State Univ., Columbus.
- Dahl, C.A., Matthews, M.E., and Marth, E.H. 1978. Cook/chill foodservice systems: microbiological quality of beef loaf at five process stages. *J. Food Prot.* 41: 788.
- Dahl, C.A. and Matthews, M.E. 1979. Forced-air convection ovens: temperature range in oven and in beef loaf during heating. *School Food Service Research Review* 3: 11.
- Dahl, C.A. and Matthews, M.E. 1980a. Cook/chill foodservice system with a microwave oven: thiamin content in portions of beef loaf after microwave-heating. *J. Food Sci.* 45: 608.
- Dahl, C.A. and Matthews, M.E. 1980b. Cook/chill foodservice systems with microwave ovens: range of temperature, yield, moisture and fat content among portions of beef loaf, potatoes, and frozen and canned green beans after microwave-heating. *J. Am. Dietet. Assoc.* 77: 289.
- Dahl, C.A., Matthews, M.E., and Marth, E.H. 1980a. Cook/chill foodservice system with a microwave oven: aerobic plate counts from beef loaf, potatoes and frozen green beans. *J. Microwave Power.* 15: 95.
- Dahl, C.A., Matthews, M.E., and Marth, E.H. 1980b. Fate of *Staphylococcus aureus* in beef loaf, potatoes and frozen and canned green beans after microwave-heating in a simulated cook/chill hospital foodservice system. *J. Food Prot.* 43: 916.
- Dahl, C.A., Matthews, M.E., and Marth, E.H. 1981a. Survival of *Streptococcus faecium* in beef loaf and potatoes after microwave-heating in a simulated cook/chill foodservice system. *J. Food Prot.* 44: 128.
- Dahl, C.A., Matthews, M.E., and Marth, E.H. 1981b. Cook/chill foodservice system with a microwave oven: injured aerobic bacteria during food product flow. *European J. Appl. Microbiol. Biotechnol.* 11: 125.
- Dahl, C.A. 1982. Hospital patient feeding systems: effect of meal assembly, meal distribution and meal service on sensory quality of food. In "Hospital Patient Feeding Systems," p. 193. National Academy Press, Washington, D.C.
- Decareau, R.V. 1978. Foodservice equipment: technological trends. *J. Food Prot.* 41: 459.
- Engler, P.P. and Bowers, J.A. 1975a. Eating quality and thiamin retention of turkey breast muscle roasted and "slow cooked" from frozen and thawed states. *Home Econ. Res. J.* 4: 27.
- Engler, P.P. and Bowers, J.A. 1975b. Vitamin B₆ in reheated, held and freshly cooked turkey breast. *J. Am. Dietet. Assoc.* 67: 42.
- Engler, P.P. and Bowers, J.A. 1976. B-vitamin retention in meat during storage and preparation. *J. Am. Dietet. Assoc.* 69: 253.
- Erdman, J.W., Jr. 1979. Effect of preparation and service of food on nutritive value. *Food Technol.* 33(2): 38.
- Erdman, J.W., Jr. and Klein, B.P. 1982. Harvesting, processing and cooking influences on vitamin C in foods. In "Ascorbic Acid: Chemistry, Metabolism, and Uses," P.A. Seib and B.M. Tolbert (Ed.), p. 499. *Adv. in Chem. Ser. 200*, American Chemical Society, Washington, D.C.
- Fennema, O. 1977. Loss of vitamins in fresh and frozen foods. *Food Technol.* 31(12): 32.
- Ferguson, V.B. 1981. Microwave and flavor: compatible? *Digest Microwave Power Symposium 1981*, p. 87. International Microwave Power Institute, Toronto, Ontario, Canada, June 9-12.
- Glew, G. 1968. Attitudes of patients to food in hospitals. *Nutrition Lond.* 22: 195.
- Glew, G. (Ed.). 1973. "Cook/Freeze Catering, an Introduction to its Technology." Faber and Faber, London, England.
- Grater, C. 1979. The caterer's requirement for food quality. In "Advances in Catering Technology," G. Glew (Ed.), p. 57. Applied Science Publishers, Ltd., London, England.
- Gross, T.J. 1983. Temperature preference of older adults for ground beef mixture served hot. M.S. thesis, Iowa State University, Ames.
- Hansson, E., Olsson, H., Bosund, I., and Rasmussen, I. 1972. Changes during warm holding of food products. (In Swedish, summary in English.) *Naringstorskning* 16: 106.
- Harris, R.S. and Karmas, E. (Ed.). 1975. "Nutritional Evaluation of Food Processing." AVI Publishing Co., Inc., Westport, CT.
- Hill, M.A., Baron, M., Kent, J.S., and Glew, G. 1977. The effect of hot storage after reheating on the flavour and ascorbic acid retention of pre-cooked frozen vegetables. In "Catering Equipment and Systems Design," G. Glew (Ed.), p. 331. Applied Science Publishers, Ltd., London, England.
- Ito, K. 1974. Microbiological critical control points in canned foods. *Food Technol.* 28(9): 46.
- Janicki, L.J. and Appledorf, H. 1974. Effect of broiling, grill frying and microwave cooking on moisture, some lipid components and total fatty acids of ground beef. *J. Food Sci.* 39: 715.
- Jonsson, L., Ohlsson, L., and Lindholm, B. 1977. Comparison of the temperature-holding capacities of three different tray distribution systems. In "Catering Equipment and Systems Design," G. Glew (Ed.), p. 295. Applied Science Publishers, Ltd., London, England.
- Kahn, L.N. and Livingston, G.E. 1970. Effect of heating methods on thiamin retention in fresh and frozen prepared foods. *J. Food Sci.* 35: 349.
- Karlstrom, B. and Jonsson, L. 1977. Quality changes during warm-holding of foods. In "Catering Equipment and Systems Design," G. Glew (Ed.), p. 315. Applied Science Publishers, Ltd., London, England.
- Kauffman, F.L. 1974. How FDA uses HACCP. *Food Technol.* 28(9): 51.
- Khan, M.A., Klein, B.P., and Lee, F.V. 1982. Thiamin content of freshly prepared and leftover Italian spaghetti served in a university cafeteria foodservice. *J. Food Sci.* 47: 2093.
- Klein, B.P. 1982. Effect of processing on nutritive values of foods: microwave cooking. In "CRC Handbook of Nutritive Value of Processed Food," vol. I, M. Reichigl (Ed.), p. 209. CRC Press, Boca Raton, FL.
- Klein, B.P., Perry, A.K., and Al-Obaidy, H. 1982. Unpublished data. University of Illinois, Urbana.
- Kossovitsas, C., Navab, M., Chang, C.M., and Livingston, G.E. 1973. A comparison of chill holding versus frozen storage on quality and wholesomeness of some prepared foods. *J. Food Sci.* 38: 901.
- Kylen, A.M., McGrath, B.H., Hallmark, E.L., and Van Duyne, F.O. 1964. Microwave and conventional cooking of meat. *J. Am. Dietet. Assoc.* 45: 139.

- Labuza, T.P. 1980. Enthalpy/entropy compensation in food reactions. *Food Technol.* 34(2): 67.
- Labuza, T.P. and Riboh, D. 1982. Theory and application of Arrhenius kinetics in the prediction of nutrient losses in food. *Food Technol.* 36(10): 66.
- Lee, F.V., Khan, M.A., and Klein, B.P. 1981. Effect of preparation and service on the thiamin content of oven-baked chicken. *J. Food Sci.* 46: 1560.
- Lenz, M.K. and Lund, D.B. 1980. Experimental procedures for determining destruction kinetics of food components. *Food Technol.* 34(2): 51.
- Livingston, G.E., Ang, C.Y.W., and Chang, C.M. 1973. Effects of food-service handling. *Food Technol.* 27(2): 28.
- Livingston, G.E. and Chang, C.M. 1979. Foodservice operation design for nutrient retention in foods. *Food Technol.* 33(3): 32.
- Longree, K. 1980. "Quantity Food Sanitation," 3rd ed. John Wiley and Sons, Inc., New York.
- Love, J. and Love, M. 1982. Unpublished data. Iowa State University, Ames.
- Lund, D.B. 1975. Effects of heat processing on nutrients. In "Nutritional Evaluation of Food Processing," R.S. Harris and E. Karmas (Ed.), p. 205. AVI Publishing Co., Inc., Westport, CT.
- Lund, D.B. 1977. Maximizing nutrient retention. *Food Technol.* 31(2): 71.
- Lund, D.B. 1979. Effect of commercial processing on nutrients. *Food Technol.* 33(2): 28.
- Lund, D.B. 1982. Quantifying reactions influencing quality of foods: texture, flavor and appearance. *J. Food Proc. Pres.* 6: 133.
- Mahaffey, M.J., Mennes, M.E., and Miller, B.B. 1981. "Food Service Manual for Health Care Institutions." American Hospital Association, Chicago, IL.
- Matthews, M.E. 1977. Quality of food in cook/chill foodservice systems: a review. *School Foodservice Research Review* 1: 15.
- Maxcy, R.B. 1976. Fate of post-cooking microbial contaminants of some major menu items. *J. Food Sci.* 41: 375.
- Milson, A. and Kirk, D. 1980. "Principles of Design and Operation of Catering Equipment." AVI Publishing Co., Inc., Westport, CT.
- Mohd-Jan, A. 1983. Spaghetti firmness and ascorbic acid and thiamine retention in spaghetti and meat sauce held hot. M.S. thesis, Iowa State University, Ames.
- Morrison, D.J. 1982. Temperature preference of third-grade children for ground beef mixture served hot. M.S. thesis, Iowa State University, Ames.
- National Restaurant Association. 1983. *National Restaurant Association News*, December, 3(11): 14.
- Nicholanco, S. and Matthews, M.E. 1978. Quality of beef stew in a hospital chill foodservice system. *J. Am. Dietet. Assoc.* 72: 31.
- Noble, I. 1964. Thiamin and riboflavin retention in broiled meat. *J. Am. Dietet. Assoc.* 45: 477.
- Noble, I. 1965. Thiamin and riboflavin retention in braised meat. *J. Am. Dietet. Assoc.* 47: 205.
- Noble, I. 1970. Thiamin and riboflavin retention in cooked variety meat. *J. Am. Dietet. Assoc.* 56: 225.
- Norris, S.D. 1981. Temperature preference of third-grade children for a food served hot. M.S. thesis, Iowa State University, Ames.
- Norwell, N.J. 1978. Effect on quality of beef loaf of varying the end point of initial heating in a simulated cook/chill hospital foodservice system. M.S. thesis, Univ. of Wisconsin, Madison.
- Ockerman, H.W. and Dowiercial, R. 1982. Evaluation of 54°C and 60°C holding temperature on aerobic plate counts and coliform determinations of control and post cooking contaminated beef roast. *J. Food Sci.* 47: 226.
- Oporum, C.F. 1981. Temperature preference of adults for a food served hot. M.S. thesis, Iowa State University, Ames.
- Paulus, K., Nowak, I.P., Zacharios, R.P., and Bognav, A. 1978. Influence of heating and keeping warm on the quality of meals. *Ann. Nutr. Alim.* 32: 447.
- Paulus, K. 1979. The constraints on food quality. In "Advances in Catering Technology," G. Glew (Ed.), p. 51. Applied Science Publishers, Ltd., London, England.
- Peterson, A.C. and Gunnerson, R.E. 1974. Microbiological critical control points in frozen foods. *Food Technol.* 28(9): 37.
- Peterson, A.B. 1981. Temperature preference of senior citizens for a food served hot. M.S. thesis, Iowa State University, Ames.
- Rambeck, U. 1979. How can the food supplier influence quality at the catering level? In "Advances in Catering Technology," G. Glew (Ed.), p. 72. Applied Science Publishers, Ltd., London, England.
- Sawyer, C.A., Naidu, Y.M., and Thompson, S. 1983. Cook/chill foodservice systems: relative microbiological quality of beef loaf, peas and potatoes after reheating by conduction, convection and microwave radiation. *J. Food Prot.* (submitted).
- Shaw, C.P., Darsch, G.P., and Tuomi, J.M. 1979. Examination of patient tray food service equipment and evaluation of the Alpha Cart. Technical Report, Natick/TR-79/036, U.S. Army, Natick Research and Development Command, Natick, MA.
- Snyder, P.O. 1982. Nutritional and microbiological quality of whipped potatoes following pre-service holding as would occur in a conventional foodservice system. M.S. thesis, Univ. of Wisconsin, Madison.
- Snyder, P.O., Matthews, M.E., and Marth, E.H. 1983. Fate of *Bacillus cereus* in whipped potatoes during pre-service holding as would occur in a conventional foodservice system. *J. Food Prot.* 46: 408.
- Thompson, J.D. and Johnson, D. 1963. Food temperature preferences of surgical patients. *J. Am. Dietet. Assoc.* 43: 209.
- Troepfer, E.W., Pritchett, C.A., and Hewstor, E.M. 1955. Boneless beef: raw, cooked, and stewed. Results of analysis for moisture, protein, fat and ash. Bull. 137, U.S. Dept. of Agriculture, Washington, D.C.
- Tuomi, S., Matthews, M.E., and Marth, E.H. 1974a. Temperature and microbial flora of refrigerated ground beef gravy subjected to holding and heating as might occur in a school foodservice operation. *J. Milk Food Technol.* 37: 457.
- Tuomi, S., Matthews, M.E., and Marth, E.H. 1974b. Behavior of *Clostridium perfringens* in precooked chilled ground beef gravy during cooling, holding, and reheating. *J. Milk Food Technol.* 37: 494.
- Unklesbay, N.F., Maxcy, R.B., Knickrehm, M.E., Stevenson, K.E., Cremer, M.L., and Matthews, M.E.

1977. Foodservice systems: product flow and microbial quality and safety of foods. North Central Regional Res. Publ. No. 245, Missouri Agric. Exp. Sta., Columbia, MO.
- USDHEW. "Food Service and Sanitation Manual—1976." Public Health Serv., HEW Pub. No. (FDA) 78-2081, Food and Drug Admin., Div. of Retail Food Protection, Washington, D.C.
- Van Dress, M.G. 1979. An overview of the food service industry. USDA National Food Review, summer.
- Van Dress, M.G. 1982. The foodservice industry: structure, organization, and use of food equipment and supplies. Statistical Bulletin Number 690, U.S. Dept. of Agriculture, Washington, D.C.
- Van Dress, M.G. and Putnam, J. 1983. American eating places. USDA National Food Review, winter.
- Voris, H.H. and Van Duyne, F.O. 1979. Low wattage microwave cooking of top round roasts: energy consumption, thiamin content and palatability. J. Food Sci. 44: 1447.
- Zabik, M.E. and Sawyer, C. 1982. Unpublished data. Michigan State University, East Lansing.
- Zallen, E.M., Hitchcock, M.J., and Goertz, G.E. 1975. Chilled food systems: effects of chilled holding on quality of beef loaves. J. Am. Dietet. Assoc. 67: 552.
- Ziprin, Y.A. and Carlin, A.F. 1976. Microwave and conventional cooking in relation to quality and nutritive value of beef and beef-soy loaves. J. Food Sci. 41: 4.

UNIVERSITY OF ILLINOIS-URBANA

Q.838.71L68
BULLETIN. URBANA
779 1984

C008



3 0112 019531257